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PROCEEDINGS
AND
TRANSACTIONS
OF THE
LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXVI.

SESSION 1911-1912.

LIVERPOOL :
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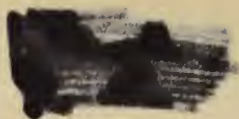
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PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY

BIOLOGY

OFFICE-BEARERS AND COUNCIL.

Ex-Presidents :

- 1886—87 PROF. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—88 J. J. DRYSDALE, M.D.
1888—89 PROF. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—90 PROF. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—91 T. J. MOORE, C.M.Z.S.
1891—92 T. J. MOORE, C.M.Z.S.
1892—93 ALFRED O. WALKER, J.P., F.L.S.
1893—94 JOHN NEWTON, M.R.C.S.
1894—95 PROF. F. GOTCH, M.A., F.R.S.
1895—96 PROF. R. J. HARVEY GIBSON, M.A.
1896—97 HENRY O. FORBES, LL.D., F.Z.S.
1897—98 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
1898—99 PROF. C. S. SHERRINGTON, M.D., F.R.S.
1899—1900 J. WIGLESWORTH, M.D., F.R.C.P.
1900—1901 PROF. PATERSON, M.D., M.R.C.S.
1901—1902 HENRY C. BEASLEY.
1902—1903 R. CATON, M.D., F.R.C.P.
1903—1904 REV. T. S. LEA, M.A.
1904—1905 ALFRED LEICESTER.
1905—1906 JOSEPH LOMAS, F.G.S.
1906—1907 PROF. W. A. HERDMAN, D.Sc., F.R.S.
1907—1908 W. T. HAYDON, F.L.S.
1908—1909 PROF. B. MOORE, M.A., D.Sc.
1909—1910 R. NEWSTEAD, M.Sc., F.E.S.
1910—1911 PROF. R. NEWSTEAD, M.Sc., F.R.S.

SESSION XXVI., 1911-1912.

President :

J. H. O'CONNELL, L.R.C.P.

Vice-Presidents :

PROF. W. A. HERDMAN, D.Sc., F.R.S.

PROF. R. NEWSTEAD, M.Sc., F.R.S.

Hon. Treasurer :

W. J. HALLS.

Hon. Librarian :

MAY ALLEN, B.A.

Hon. Secretary :

JOSEPH A. CLUBB, D.Sc.

Council :

HENRY C. BEASLEY.
R. CATON, M.D., F.R.C.P.
H. B. FANTHAM, D.Sc., B.A.
W. T. HAYDON, F.L.S.
J. JOHNSTONE, B.Sc.
J. SHARE-JONES, F.R.C.V.S.

PROF. B. MOORE, M.A., D.Sc.
DOUGLAS LAURIE, M.A.
W. S. LAVEROCK, M.A., B.Sc.
PROF. SHERRINGTON, F.R.S.
W. M. TATTERSALL, D.Sc.
E. THOMPSON.

Representative of Students' Section :

R. ROBBINS (Miss).

REPORT of the COUNCIL.

DURING the Session 1911-12 there have been seven ordinary meetings and one field meeting of the Society.

The communications made to the Society at the ordinary meetings have been representative of almost all branches of Biology, and the various exhibitions and demonstrations thereon have been of great interest.

Prof. F. W. Gamble, D.Sc., F.R.S., of Birmingham, lectured before the Society, at the February Meeting, on "Methods and Results of Symbiosis."

The Library continues to make satisfactory progress, and additional important exchanges have been arranged.

The Treasurer's statement and balance-sheet are appended.

The members at present on the roll are as follows:—

Ordinary members	-	-	-	-	-	-	45
Associate members	-	-	-	-	-	-	5
Student members, including Students' Section	-						37
							<hr/>
Total	-						87
							<hr/>

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the twenty-sixth session was held at the University, on Friday, October 13th, 1911.

The President-elect (J. H. O'Connell, L.R.C.P.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1910-1911 (see "Proceedings," Vol. XXV., p. viii.) was submitted and adopted.
2. The Treasurer's Balance Sheet for the Session 1910-1911 (see "Proceedings," Vol. XXV, p. xx.) was submitted and approved.
3. The following Office-bearers and Council for the ensuing Session were elected:—Vice-Presidents, Prof. Herdman, D.Sc., F.R.S., and Prof. Newstead, M.Sc., F.R.S.; Hon. Treasurer, W. J. Halls; Hon. Librarian, May Allen, B.A.; Hon. Secretary, Joseph A. Clubb, D.Sc.; Council, H. C. Beasley, Dr. Caton, Dr. Fantham, W. T. Haydon, F.L.S., J. Johnstone, B.Sc., J. Share-Jones, F.R.C.V.S., Prof. B. Moore, M.A., D.Sc., W. S. Laverock, M.A., B.Sc., Douglas Laurie, M.A., Prof. Sherrington, F.R.S., and E. Thompson.
4. J. H. O'Connell, L.R.C.P., delivered the Presidential Address on "Reptiles in Captivity" (see "Transactions," p. 1). A vote of thanks was proposed by Dr. Dakin, seconded by Mr. Laurie, and carried with acclamation.

The second meeting of the twenty-sixth session was held at the University, on Friday, November 10th, 1911. The President in the chair.

1. Dr. Clubb exhibited with remarks a living specimen of *Cinixys crosa*, from West Africa.
 2. Prof. Herdman exhibited a collection of Marine Invertebrates dredged from Hebridean seas during the summer.
 3. Prof. Herdman submitted the Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station (see "Transactions," p. 13).
-

The third meeting of the twenty-sixth session was held at the University, on Friday, December 15th, 1911. The President in the chair.

1. Mr. H. C. Beasley exhibited with remarks some specimens of peaty material from Leasowe, with fungus investing it.
 2. Dr. Dakin submitted a paper on the "Osmotic pressure of the blood of Aquatic Animals."
-

The fourth meeting of the twenty-sixth session was held at the University, on Friday, January 12th, 1912. The Vice-President (Prof. Herdman) in the chair.

1. Dr. H. B. Fantham communicated a paper on "Some Flagellate Parasites of Insects—not always harmful—and their relation to

Trypanosomes." The parasites discussed belong to the genera *Herpetomonas* and *Crithidia* and occur in the digestive tracts of insects such as flies, mosquitos and water-bugs. The herpetomonad found in the latex of various *Euphorbia* and the parasite of Kala-azar were mentioned.

The fifth meeting of the twenty-sixth session was held at the University, on Friday, February 9th, 1912, jointly with the Students' Section of the Society.

1. Prof. F. W. Gamble, F.R.S., of Birmingham, lectured before the Society on "Methods and Results of Symbiosis."
-

The sixth meeting of the twenty-sixth session was held at the University, on Friday, March 8th, 1912. The President in the chair.

1. Prof. Newstead lectured to the Society on "Notes on the Natural History of Nyassaland," giving a most interesting account of his recent visit to that country.
-

The seventh meeting of the twenty-sixth session was held at the University, on Friday, May 10th, 1912. The President in the chair.

1. Prof. Herdman submitted the Annual Report of the Investigations carried on during 1911 in con-

nection with the Lancashire Sea Fisheries Committee (see "Transactions," p. 71).

2. L.M.B.C. Memoir on the Whelk, by Dr. Dakin (see "Transactions," p. 253).

The eighth meeting of the twenty-sixth session was the Annual Field Meeting held at Hilbre Island, on Saturday, June 1st. At the short business meeting held after tea, on the motion of the President from the chair, Mr. James Johnstone, B.Sc., was unanimously elected President for the ensuing session.

LIST of MEMBERS of the LIVERPOOL
BIOLOGICAL SOCIETY.

SESSION 1911-1912.

A. ORDINARY MEMBERS.

(Life Members are marked with an asterisk.)

ELECTED.

- 1908 Abram, Prof. J. Hill, 74, Rodney Street,
Liverpool.
- 1909 *Allen, Miss May, B.A., HON. LIBRARIAN, Univer-
sity, Liverpool.
- 1910 Barratt, Dr. J. O. Wakelin, Cancer Research
Laboratory, University, Liverpool.
- 1888 Beasley, Henry C., 25a, Prince Alfred Road,
Wavertree.
- 1908 Bigland, H. D., B.A., Shrewsbury Road,
Birkenhead.
- 1903 Booth, jun., Chas., 30, James Street, Liverpool.
- 1886 Caton, R., M.D., F.R.C.P., 78, Rodney Street.
- 1886 Clubb, J. A., D.Sc., HON. SECRETARY, Free Public
Museums, Liverpool.
- 1909 Dakin, W., D.Sc., The University, Liverpool.
- 1911 Ellison, George, 4, Loudon Grove, Liverpool.

- 1910 Fantham, Dr. H. B., School of Tropical Medicine,
University, Liverpool.
- 1902 Glynn, Dr. Ernest, 62, Rodney Street.
- 1886 Halls, W. J., HON. TREASURER, 35, Lord Street.
- 1910 Hamilton, Mrs. J., 92, Huskisson Street, Liver-
pool.
- 1896 Haydon, W. T., F.L.S., 55, Grey Road, Walton,
Liverpool.
- 1886 Herdman, Prof. W. A., D.Sc., F.R.S., VICE-
PRESIDENT, University, Liverpool.
- 1893 Herdman, Mrs. W. A., Croxteth Lodge, Ullet
Road, Liverpool.
- 1902 Holt, A., Crofton, Aigburth.
- 1903 Holt, George, Grove House, Knutsford.
- 1903 Holt, Richard D., M.P., 1, India Buildings,
Liverpool.
- 1898 Johnstone, James, B.Sc., University, Liverpool.
- 1894 Lea, Rev. T. S., D.D., The Vicarage, St. Austell,
Cornwall.
- 1896 Laverock, W. S., M.A., B.Sc., Free Museums,
Liverpool.
- 1906 Laurie, R. Douglas, M.A., University, Liverpool.
- 1905 Moore, Prof. B., D.Sc., F.R.S., University,
Liverpool.
- 1904 Newstead, Prof. R., VICE-PRESIDENT, M.Sc.,
F.R.S., School of Tropical Medicine, Liverpool.
- 1904 O'Connell, Dr. J. H., PRESIDENT, 38, Heathfield
Road, Liverpool.
- 1904 Pallis, Miss M., Tatoi, Aigburth Drive, Liverpool.
- 1903 Petrie, Sir Charles, Ivy Lodge, Ashfield Road,
Aigburth, Liverpool.
- 1903 Rathbone, H. R., Oakwood, Aigburth.
- 1890 *Rathbone, Miss May, Backwood, Neston.

- 1910 Riddell, Wm., M.A., Zoological Department,
University, Liverpool.
- 1897 Robinson, H. C., Malay States.
- 1908 Rock, W. H., 25, Lord Street, Liverpool.
- 1894 Scott, Andrew, A.L.S., Piel, Barrow-in-Furness.
- 1908 Share-Jones, John, F.R.C.V.S., University,
Liverpool.
- 1895 Sherrington, Prof., M.D., F.R.S., University,
Liverpool.
- 1886 Smith, Andrew T., 21, Croxteth Road.
- 1903 Stapledon, W. C., "Annery," Caldy, West Kirby.
- 1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liver-
pool.
- 1905 Thompson, Edwin, 25, Sefton Drive, Liverpool.
- 1889 Thornely, Miss L. R., Nunclose, Grassendale.
- 1888 Toll, J. M., 49, Newsham Drive, Liverpool.
- 1891 Wiglesworth, J., M.D., F.R.C.P., County
Asylum, Rainhill.

B. ASSOCIATE MEMBERS.

- 1905 Carstairs, Miss, 39, Lilley Road, Fairfield.
- 1905 Harrison, Oulton, Denehurst, Victoria Park,
Wavertree.
- 1910 Kelley, Miss A. M., 10, Percy Street, Liverpool.
- 1903 Tattersall, W. D., D.Sc., The Museum, Man-
chester.
- 1910 Tozer, Miss E. N., Physiology Laboratory, The
University, Liverpool.

C. UNIVERSITY STUDENTS' SECTION.

President: Miss R. Robbins.

Hon. Secretary: Miss C. M. P. Stafford.

Members:

The Misses Gleave, Robinson, Latache, Gill, Edmondson, Platt, Bradley, Cavanagh, Lewis, Kay, E. Smith, Illingworth, Thornton, Hewitt, Hodgson, Quirk, Payne, Brew, Millican, Clerke, Kirk, Udall, Garside, Little, Higson, Robinson, Clegg and Upson; Messrs. Waterhouse, Goodburn, Rowlands, Barlow, Daniel and Hamilton.

D. HONORARY MEMBERS.

S.A.S., Albert I., Prince de Monaco, 10, Avenue du brocadéro, Paris.

Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.

Claus, Prof. Carl, University, Vienna.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Haeckel, Prof. Dr. E., University, Jena.

Hanitsch, R., Ph.D., Raffles Museum, Singapore.

Solms-Laubach, Prof.-Dr., Botan. Instit., Strassburg.

THE LIVERPOOL BIOLOGICAL SOCIETY.

Dr.

IN ACCOUNT WITH W. J. HALLS, HON. TREASURER.

Cr.

1911, Oct. 1st, to Sept. 30th, 1912.	£	s.	d.	1911, Oct. 1st, to Sept. 30th, 1912.	£	s.	d.
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" Messrs. Tinling & Co.	37	0	0	" Associate Members	1	1	0
" Hon. Secretary's Expenses	2	6	0	" Student Member		5	0
" Hon. Librarian's Expenses	2	19	10	" Entrance Fee		10	6
" Balance	7	6	4	" Subscriptions in Arrear	8	8	0
				" Subscriptions in Advance	3	3	0
				" Students' Society, for Teas		2	6
				" Sale of Volumes	9	3	6
				" Bank Interest		5	7
					£53	5	8

Audited and found correct,

LIVERPOOL, October 4th, 1912.

HENRY C. BEASLEY.

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

INAUGURAL ADDRESS
ON
REPTILE LIFE IN CAPTIVITY.

By JOHN H. O'CONNELL, L.R.C.P.,
PRESIDENT.

In selecting reptile life as the subject of this evening's address, I propose to deal with the matter from the Natural History side of the question, and to show how far it is possible to approximate their artificial to their natural conditions. It is a frequent reproach against this group that they are sluggish and more or less inert, and in many cases this is so because the conditions of their captivity are entirely unsuitable to their lives. This group is not without its fascination, and the romantic weirdness of its past history awakens many an echo in the fairy tales of childhood and the folk-lore of nations.

What an interesting ancestry to look back on, in the dim and distant ages of the past, in the Jurassic period, when vast tracts of primeval forests clothed the earth with a plant life long since gone; the period of the passing of the giant fern-like forms, and the great horse-tails of the Carboniferous swamps, and the coming of the Cycads. The glory of this race has gone into the long and never-ending night where oblivion, in enshrouding the past history of the race, has almost closed the book of nature and, indeed, would have done so had they not literally left "foot prints in the sands of time"; and had not the casts of their bones been taken first in mud and afterwards perpetuated in rock.

Our present interest is with the descendants of the great past dead. The majority of reptiles come from tropical countries, and this is the first difficulty in the way of keeping them in a temperate climate. It is very rare that the temperature of the British Isles is high enough to suit these animals, and we must accordingly resort to artificial heating. We must study the most suitable temperature, light and feeding. However, there are a few general considerations to be investigated first. Most reptiles, when free, hibernate during the colder months in their own climates, as also our own snakes and lizards, but prior to doing so they store up sufficient fat to carry them through their sleep. This raises an interesting point as to whether hibernation is essential to the well-being of a reptile or not; many foreign lizards have lived more than one winter in our climate in an artificial temperature, some indeed for several years, without, apparently, any bad effects resulting from suspension of hibernation. These cases would seem to show that this resting stage is not a physiological necessity to every lizard. On the other hand, some years ago, I kept some green lizards which I had collected in Jersey, partly through a winter at a suitable heat. They did not do very well and most of them died before the winter ended. I find the Amphibia behave much as the reptiles do, for on another occasion a British toad had been allowed to go into its winter sleep and after two or three weeks it was put back into the heated case. It was completely upset and did not resume feeding for a very long time.

70° F. is a good average heat at which to maintain most reptiles; this may be done by direct heat under the case, the bottom of which is covered with sand, or to have the case over a heated water bath. The best and

most economical method is by using a small copper boiler with copper pipes, in which hot water can circulate in a tray under the case.

Unfortunately, lizards require a considerable amount of sunshine before they will feed or do well, and are thus the most difficult group to deal with. Some of the desert species are particularly difficult to keep.

The Crocodilia are probably the easiest to manage. Their cases should contain a tank sufficiently large to enable them to move about with freedom, and deep enough for them to remain completely submerged if they so wish. In addition it is advisable to have a dry part for them to come out of the water and bask in the sun. They will feed freely on raw meat, fish, small frogs or even insects. There is a marked difference in the temperaments of these creatures. The long-snouted W. African crocodile (*C. cataphractus*) is a timid animal, not much given to biting, while its ally the common crocodile (*C. niloticus*) is always vicious and treacherous; *C. americanus* is very pretty when small and docile; *C. porosus*, an Indian species, is usually vicious. *Osteolaemus tetraspis*, from the W. Coast of Africa, is an interesting species to keep; it is short and heavily built and nicely mottled and marked.

Of all the Crocodilia, the Mississippi Alligator is the most suitable for captivity as it is especially docile and quickly recognises its feeder. The natural cry of this group is something between a grunt and a bark, and they are remarkably sensitive to the lightest touch over the shields of their backs and sides, and will get into the strangest positions in their endeavours to remove the source of annoyance. Swimming is usually performed by vigorous strokes of the tail with the limbs pressed close to the sides of the body.

The water tortoises require similar conditions to those of crocodiles. These may be easily distinguished by the flattened webbed feet and usually depressed carapaces. Most of the water forms are animal feeders and tear their food with their long and sharp claws. It is necessary to be very careful in handling the larger ones as they bite very badly, usually taking out a piece of one's finger.

The large Amazon fresh water tortoise (*Podocnemis*) seems to be a vegetable feeder. Some years ago a specimen measuring eighteen inches long was brought to me dead, and on opening it I found it was packed with seeds resembling those of the sycamore and another type resembling pepper berries. I planted some of the former and a few germinated and put forth the dicotyledons, but died before its true leaves came, as the cold weather set in. Most of the seeds and berries had been bitten, I presumed that they must have fallen into the water and then been taken as food. Most land tortoises are vegetable feeders, and will hibernate if they have been feeding well and are put into earth or moss.

These two groups are comparatively easily dealt with, they will feed readily and are not much subject to diseases. Yet there are certain conditions to be aware of. Crocodiles should not be fed entirely on meat, as there is a tendency for their bones to become softened, no doubt due to an insufficiency of lime salts. However, apart from this, they are liable to injure their jaws and teeth in biting at any hard substance introduced into the case, and afterwards developing obstinate sores. The Caspian tortoise (*Clemmys caspica*) has often patches of diseased bone in its carapace, and in separating, openings are left.

The Ophidia are very much more difficult to look after, not so much on account of the heat or light as

their susceptibility to diseases and the infectious nature of these conditions. The most dreaded affection is a membranous condition of the mouth which spreads to the fauces, and is known as "canker." This disease gains entry to the mucous membrane inside the lips and jaws through injury or abrasion. The animal becomes ill-tempered and snappish, and ultimately dies, partly as the result of starvation, through the inability of the tissues to absorb food stuffs, and also partly from toxins formed by the growth.

Another snake disease is known as "casting disease," and means that no sooner is the old slough cast than another one begins, with the result that in a bad case the unfortunate snake gets covered with a more or less thick felted mass of partly shed scales. While snakes are casting they will refuse food, and more especially when in this chronic state. For canker I know of no actual cure, but have always made a rule of isolating the infected specimen and disinfecting the case thoroughly to try and prevent the spread of this scourge. Casting disease can at times be cured by bathing the animal in water to which a little glycerine has been added.

Snakes are carnivorous reptiles and require water for drinking and bathing. They show considerable diversity in their methods of taking their prey, the poisonous species strike and usually wait the victim's death. The constrictors kill their prey by encircling its body with their own folds, while others, as the grass snakes—*Tropidonotus*—swallow frogs alive, catching them by a leg.

It is possible to get the pythons and boas to take dead animals, but even then they will constrict them. The capture and death of an animal by a constricting snake is a remarkable process. Assuming that a rat is

put into a boa's case, the snake glides towards it and when quite close it will investigate it. Then, apparently satisfied that all is right, it will retract its neck and suddenly dart forward, usually catching the animal by the side of its head or neck, and a combined movement follows, the snake draws its prey towards it and throws a coil or two of its body round the luckless animal. Should it struggle vigorously, additional coils are brought into play, and it is held until dead, a matter of two or three minutes. I do not think there can be much, if any, pain as asphyxia sets in rapidly. It is often said that a python pours saliva over its victim before swallowing it, this I have never observed. The animal when dead is released in order to be swallowed head first, but no saliva is poured over it. Another point often brought forward is the supposed fascination and terror of the animals used for feeding these snakes. There is no such thing. Whether the intended food is rat, rabbit, or bird, no signs of fear are shown, but on the contrary the victim will placidly feed in close proximity to the snake.

The Pythoninae, as a group, are most interesting, and become very docile in a short while. The common boa (*B. constrictor*) is a frequently kept species, as it is one of the handsomest and also one of the hardiest of them all. It will readily take mice, birds, rats, or rabbits, according to its size. It is very inquisitive and will examine its surroundings or a stranger minutely; it is somewhat nervous, but soon gets to know its attendant. A rather remarkable fact in its economy—at least in specimens up to six or eight feet—is the apparent absorption of all the lime taken in the bodies of its victims. I mention this matter with some reserve, although I have failed—spectroscopically—to detect lime

in the excreta. The excreta consist of hair masses, entangled in which are a few small bones, which thus have escaped the very active gastric juices, and almost solid masses of uric acid.

A word of warning may be given to collectors and others—and it is this: never put a freshly imported specimen into a case with snakes which one knows are healthy, always isolate the new arrival as it is quite possible that it may have canker.

The black python (*P. seba*) of W. Africa is frequently imported, and grows rapidly and does well in captivity, as also does the Indian (*P. molurus*). On the other hand, *P. regius* is not a satisfactory feeder. I had an unfortunate experience with a small snake of this species once. It had not fed with me, and I had put a rat weighing six ounces into the cage for a larger snake. I may mention the small python also weighed six ounces. It seized the rat and killed it, and with great difficulty swallowed it, but only survived its meal some twenty-four hours.

Snakes renew their epidermal shields periodically, the young ones will cast every couple of weeks, and the process becomes less frequent as the snake grows.

Many exaggerated stories are told of the large animals taken by the constrictors as food, but it is recognised that a snake can only swallow prey the greatest diameter of which does not exceed that of the snake's neck by three times.

A boa in my possession increased from $2\frac{1}{2}$ lbs. to 7 lbs. in a year. Certain snakes will not feed readily in captivity and must be fed artificially. This is best done by means of a smoothly ground glass tube, which is inserted into the snake's mouth and chopped meat gently pushed down. It is necessary to be very careful

during the operation as any laceration of the mucous membrane may easily lead to canker. When a snake bites it does not as a rule retain its hold, and this is true for the constrictors, unless they have seized prey; and this is directly the reverse of the next group, the lizards. When the latter bite they usually hold on firmly, grinding their teeth into one's hand. It is advisable to use great caution when the larger ones are being handled.

Lizards are rather more difficult to deal with in a satisfactory manner in captivity.

As mentioned before, they require an amount of sunshine before they will feed readily, quite independently of the temperature of the case. The British species, of course, do not require artificial heat, but will feed well and remain active during the day, only becoming dull at night time.

Most lizards are carnivorous and will eat worms and insects of all sorts, the larger kinds will take mice or small birds. Very few groups show such diversity of form and special adaptability for various modes of life as do these creatures. There are the water species, mostly with compressed bodies and tails; the tree living ones, with more or less long whip-like tails and strong claws; the flattened sand or desert species; the curious Geckos, with their palmate lamellated discs which enable them to cling to the sides of walls and to run up to and across ceilings. A remarkable peculiarity of many lizards is the ease with which they part with a portion of their tails, owing to a special mode of articulation, and which no doubt aids them often in avoiding capture; another use of the tail is as a balancing organ while running or climbing.

Among the larger ones which are commonly

imported we may mention the Monitors, these are usually long and lithe looking and somewhat suggestive of the Ophidia. The head is flattened and elongate, and armed with sharp teeth. A curious power is possessed by this group, or to be correct, especially noticeable in this group, and it is that they seem to be able to bend their jaws when biting, so that when one gets hold of a finger the anterior portion of the jaw is not thrown out of action; and they hold on most determinedly and give a very serious bite. They will also fight amongst themselves. Their food consists of meat, small mammals or birds.

The tuberculated Iguana is a very handsome species of a bright leaf-green colour with darker marks which are white edged. They feed best, in captivity, on bananas, and require a branch to climb on. Like the Monitors, they are not above using their long whip-like tails as weapons of offence or defence.

The Mastigures are found in India and N. Africa, and have compressed bodies which are covered with small scales like grains of sand. Their tails are armed with formidable spines.

As a rule, they are difficult to keep, but this summer I kept several in a heated case in a small conservatory, to which the sun had full access. The temperature used to go up to 100° F.; and all fed ravenously on cabbage and lettuce, and they drank water freely. Their activity in this heat was wonderful.

The Geckos, being nocturnal, are seen best at night, when they will run up the glass sides and dart about after insects with great rapidity. The pretty little Anoles have some power of changing their colour, but not nearly as much as the Chameleons.

The stump-tailed Australian lizard (*Trachysaurus*

rugosus) is twelve or eighteen inches long, and has large scales like miniature fir cones on its head and back. There are two poisonous lizards, known as Gila monsters (*Heloderma horridum* and a second *H. suspectum*), they certainly seem to have the power of killing small mammals or birds with their salivary secretion.

In appearance the common Gila monster is a dusky colour with broad yellowish bars across its back, and the scales are tuberculated.

Many of these creatures become quite tame and learn to know their attendant, and will watch for feeding time.

Tortoises present very little difficulties in the way of keeping. Land species will usually feed readily on green vegetables or fruit; the African genus *Cinixys* has only eaten bananas with me. Needless to say, they require an even heat.

The water tortoises are among the most interesting of this group; they are all carnivorous, with a very few exceptions.

The members of the American genus *Chrysemys* are prettily marked when young, many of them having a remarkable colour scheme, in which red, yellow, brown or green predominates, and the general effect is very striking. The best known is probably *C. picta*, which has an olive carapace with yellowish or reddish stripes outlining the shields of the back. Each marginal shield has a circular red line on it, and the same colour is seen on the under sides of these shields. The plastron is yellow. They are to be had from the dealers, ranging from one to three inches long, and will take small pieces of meat or worms. Water living species have flat webbed feet and swim well.

A remarkable animal is the Alligator terrapin, a

lumbering brute, with a large head, which it cannot retract within its shell, a long scaly tail, and is very vicious. A bite from a specimen a foot long would be a very serious matter, as it has strong hooked jaws, and takes every opportunity of snapping.

The Trionyx group is remarkable in having a small amount of bony shields in their carapaces and plastra, and in being covered with soft skin. They are flattened, and as the name implies, have only three nails on their feet. Their nostrils end in a tubular prolongation, and the horny jaws are sheathed in skin, yet the larger members of this group are very savage.

A long experience with reptiles and amphibia has afforded many opportunities of noticing remarkable facts about them. On one occasion an agama, six inches long, and a small stumpy-nosed crocodile shared the heated case with a large S. African bull frog (*Rana adspersa*). The former was missed, and as suspicions rested on the large frog—which was seven inches long from tip of snout to vent—the amphibian was made to disgorge its meal and the lizard revived. Ultimately, it and the small crocodile were eaten by the huge frog, which could also take mice as food. Most reptiles are cannibalistic and will not hesitate to kill and eat their own kind. A common chameleon caught and killed a small anole, which was dashing about its case, before it could be stopped.

Another chameleon caught a triton and bit it severely; but in this case the biter was bit, as in spite of being attended to at once the toxins of the newt proving too much for the attacker; and the former died within half an hour.

Chameleons are easily kept while the summer and autumn months are in force, but as soon as winter

approaches, even if one has a stock of blue-bottles hatched artificially, they usually die. It is necessary to supply all reptiles with water, and certain species will require spraying with water to keep them satisfactorily. This is particularly the case with Mastigures.

Phrynosoma is not an easy species to keep, but very much more difficult is the skink (*Scincus officinalis*), which requires a very high temperature and an abundance of sunlight.

One could expand notes and memories of strange happenings while observing various species of the reptilia while in captivity, but what strikes one most in this group is the keenness of its members and their ever alert watch on their surroundings, and they help to make us realize what an earth peopled with the monsters of the past must have been, and, incidentally, what small chances the human race would have had in conflict with them.

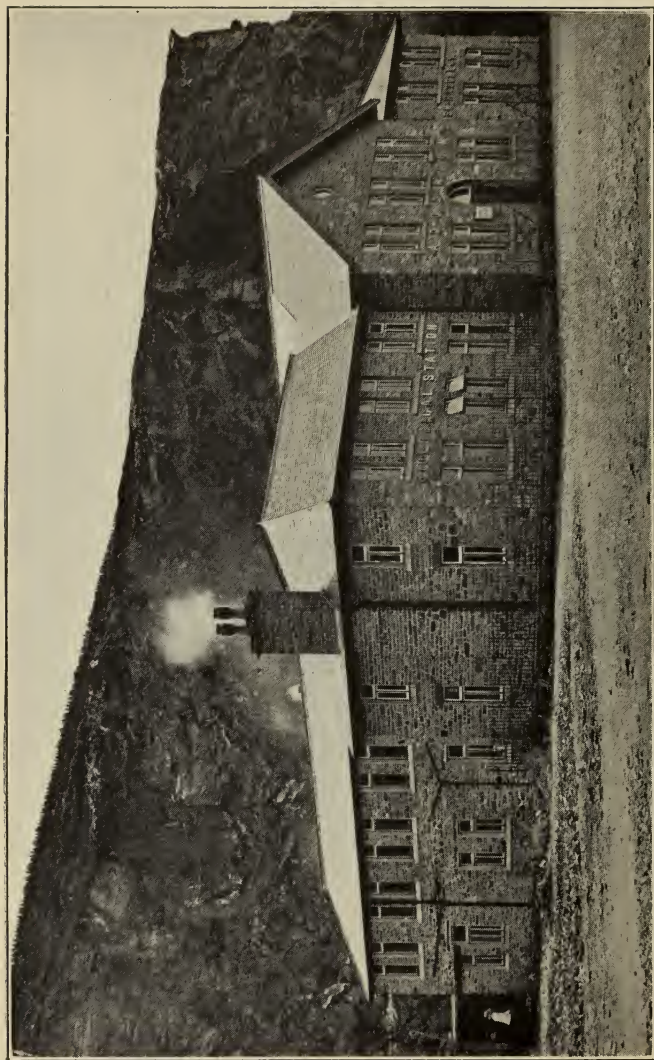


FIG. 1. The Port Erin Biological Station from the North East.

[From a photograph by Prof. F. J. Cole.]

THE
MARINE BIOLOGICAL STATION AT PORT ERIN
BEING THE
TWENTY-FIFTH ANNUAL REPORT
OF THE
LIVERPOOL MARINE BIOLOGY COMMITTEE.

Again we are happy in not having to record any changes in the Committee or on the Staff. The year has been a good one both in weather and in work, and we are able to show an increased number both of investigators in the Laboratory and of visitors to the Aquarium. The new research wing added last winter, and described fully in the last Report, has relieved pressure, and has proved quite satisfactory and most useful—especially during the Easter vacation. The enlarged library is a pleasant room, and is useful, not merely to accommodate the books, but as a sitting-room common to all workers in the building for purposes of reading, writing and occasional meetings. We have now abundance of room for additional books on the shelves; our present library of about 310 volumes and 620 Reports and pamphlets looks rather a meagre collection, and a considerable addition to the library of marine biology is one of our most pressing needs.

Figure 1 (frontispiece) shows the Biological Station in its present condition from a photograph taken last Easter, after the additions were opened for work; and fig. 2 gives the back view of the new wing, with its door to the yard and the outside stair to the upper floor. The library windows are seen in the latter figure under the low-sloping roof, between the research wing and the back of the aquarium. The ground plan (fig. 3) makes the accommodation clear on both floors.

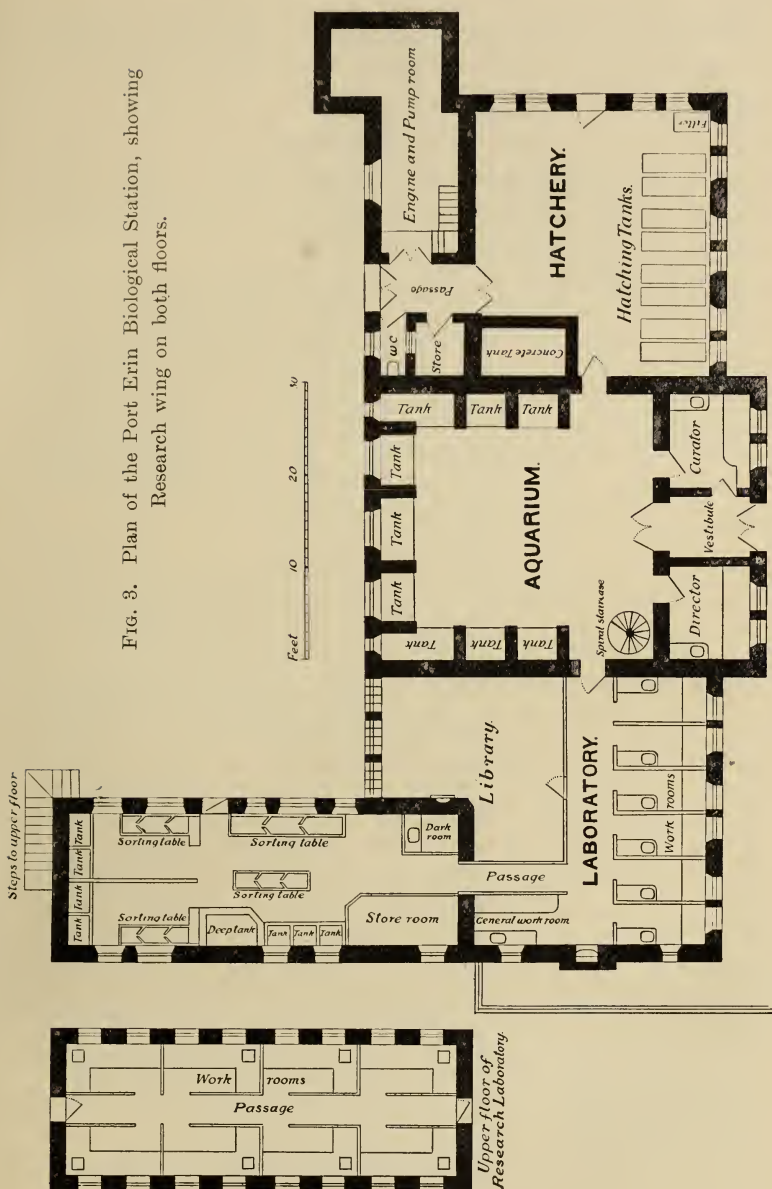
The usual Easter Vacation Class in Marine Biology, as a branch of Nature Study, was carried on with the usual success during April, under the guidance of Mr. Douglas Laurie and Dr. Dakin; and, in addition, Professor Harvey Gibson held a course of lectures and practical work on Marine Algæ for Students of Botany. Further details in regard to both these courses are given below. Professor Cole again brought a contingent of his senior students from University College, Reading. We had a group of workers from Queen's College, Cork; and altogether six different Universities or Colleges have been represented in the Laboratory.



FIG. 2. Back of the Biological Station, from the yard.

As on previous occasions, I shall first give the statistics as to the occupation of the "Tables" during the year, then will follow the "Curator's Report," and the reports that have been sent to me by various

FIG. 3. Plan of the Port Erin Biological Station, showing Research wing on both floors.



investigators on the work they have done, and, finally, I shall describe some of the researches upon which I have been myself engaged.

THE STATION RECORD.

Sixty researchers and students have occupied the Work-Tables in the Laboratories for varying periods during the year, as follows:—

<i>Dec. 27th to Jan. 9th.</i>	Professor Herdman.—Official.
<i>March 24th to April 4th.</i>	Professor F. J. Cole.—Educational.
„	Mr. H. L. Hawkins.—Echinodermata.
„	Mr. Malpas.—General.
„	Miss Attride.—General.
<i>March 24th to April 6th.</i>	Miss Davies.—General.
„	Miss Freeman.—General.
<i>March 27th to April 10th.</i>	Mr. S. Mangham.—Nutrition in Marine Algæ.
<i>March 28th to April 11th.</i>	Mr. E. W. Shann.—General
„	Dr. W. M. Tattersall.—Embryology of Littorina.
„	Miss Kyffin.—General.
„	Miss Stewart.—General.
„	Miss Payne.—General.
„	Miss Lindsey.—General.
„	Miss Pearce.—General.
<i>March 25th to April 29th.</i>	Professor Herdman.—Plankton.
„	Mr. W. Riddell.—Plankton and Polychæta.
„	Dr. Dakin.—Buccinum.
<i>April 7th to 11th.</i>	Mr. R. D. Laurie.—Educational.
<i>April 4th to 24th.</i>	Mr. H. G. Jackson.—Eupagurus.
„	Mr. W. H. Evans.—Physiology of Invertebrates.
„	Miss Latarche.—Biometry.
„	Miss Jackson.—General.
„	Miss Jolley.—General.
„	Miss Scott.—General.
„	Miss Robinson.—General.
„	Miss Gleave.—General.
„	Miss Coburn.—General.
„	Miss Lewis.—General.
„	Miss Bamber.—General.
„	Miss Robbins.—General.
„	Miss Gill.—General.
„	Miss Firth.—General.
„	Mr. Daniel.—General.
<i>April 7th to 22nd.</i>	Mr. R. H. Compton.—Marine Algæ.
<i>April 8th to 22nd.</i>	Miss Hood.—General.
„	Miss Onions.—General.
<i>April 13th to 29th.</i>	Prof. B. Moore.—Physiology of Invertebrates.
<i>April 13th to 25th.</i>	Professor R. J. Harvey Gibson.—Educational.
<i>April 13th to 29th.</i>	Mr. E. Whitley.—Physiology of Invertebrates.
<i>April 14th to 25th.</i>	Mr. W. A. Gunn.—General.
<i>April 15th to 22nd.</i>	Mr. J. C. Johnson.—Marine Algæ.
„	Miss Duke.—Marine Algæ.
„	Miss Dubbin.—Marine Algæ.
„	Mr. Mosley.—General.
„	Mr. Megson.—General.

<i>April 14th to 24th.</i>	Miss Knight.—Marine Algæ.
"	Miss Howlett.—Marine Algæ.
"	Miss Edge.—Marine Algæ.
"	Miss Stubbs.—Marine Algæ.
"	Miss Galloway.—Marine Algæ.
"	Miss Grundy.—Marine Algæ.
"	Miss Gleave.—Marine Algæ.
"	Miss Molyneux.—Marine Algæ.
"	Miss Beardsworth.—Marine Algæ.
<i>June 3rd to 6th.</i>	Professor Herdman.—Official.
<i>July 7th.</i>	Professor Herdman.—Plankton.
"	Mr. W. Riddell.—Plankton.
<i>July 10th to August 19th.</i>	Dr. H. E. Roaf.—Physiology of Invertebrates.
<i>July 17th to 28th.</i>	Mr. R. A. Wardle.—General.
"	Mr. Holden.—Marine Algæ.
<i>August 21st to Sept. 4th.</i>	Mr. J. C. Waller.—General.
<i>August 23rd to Sept. 15th.</i>	Professor B. Moore.—Bio-Chemistry of Echinus.
<i>August 23rd to Sept. 19th.</i>	Professor Herdman.—Plankton.
<i>Sept. 5th to 18th.</i>	Mr. W. A. Gunn.—General.
<i>Sept. 6th to 19th.</i>	Mr. Bury.—General.
<i>Sept. 7th to 19th.</i>	Mr. W. Riddell.—Plankton.
<i>Sept. 8th to 28th.</i>	Dr. Dakin.—Buccinum.
<i>Sept. 23rd to 30th.</i>	Mr. E. Hamilton.—General.

The "Tables" in the Laboratory were occupied as follows:—

Liverpool University Table:—

Professor Herdman.	Mr. E. Hamilton.
Dr. H. E. Roaf.	Mr. Gunn.
Dr. Dakin.	Professor B. Moore.
Mr. H. G. Jackson.	Mr. Whitley.
Professor R. J. Harvey Gibson.	Miss Latarche.
Mr. Laurie.	Mr. W. H. Evans.

Liverpool Marine Biology Committee Table:—

Mr. S. Mangham.	Mr. Megson.
Mr. Mosley.	Mr. Bury.
Mr. Riddell.	Mr. J. C. Waller.
Mr. R. H. Compton.	

Manchester University Table:—

Dr. W. M. Tattersall.	Miss Lindsey.
Mr. Holden.	Mr. R. A. Wardle.
Miss Payne.	Miss Stewart.
Mr. E. W. Shann.	Miss Pearee.
Miss Kyffin.	

Birmingham University Table:—

Miss Hood.	Miss Onions.
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University College, Reading, Table:—

Professor F. J. Cole.	Miss Davies.
Miss Attridge.	Mr. Malpas.
Mr. H. L. Hawkins.	Miss Freeman.

The following senior students of Liverpool University, and of Queen's College, Cork, occupied the Laboratory for periods varying from a fortnight to three weeks during the Easter vacation, and worked together

under the supervision of Professor Harvey Gibson, Dr. Dakin and Mr. Laurie.

Miss Jackson.	Miss Jolley.	Miss Scott.
Miss Robinson.	Miss Gleave.	Miss Coburn.
Miss Lewis.	Miss Bamber.	Miss Robbins.
Miss Gill.	Miss Firth.	Mr. Daniel.
Miss Knight.	Miss Howlett.	Miss Edge.
Miss Stubbs.	Miss Galloway.	Miss Grundy.
Miss F. Gleave.	Miss Molyneux.	Miss Beardsworth.
*Mr. J. C. Johnson.	*Miss Duke.	*Miss Dubbin.

In addition to these workers, the Station has been visited during the year by several travellers interested in Natural Science and Education, by various groups of more senior school pupils with their teachers, and by members of scientific societies.

We have been endeavouring for some years to bring the Aquarium and Museum more closely into connection with the educational system of the Island, and I am glad to say that a beginning has now been made. Mr. Ashton, the Headmaster of the Secondary School, sends eighteen of his boys every Wednesday afternoon for a lecture and practical demonstration, from our Curator, lasting from 2-30 to 4 o'clock. Mr. Chadwick writes to me after the first of these:—"I began with a lesson on the Protozoa, and after a short lecture, with plenty of black-board sketches, I got out a couple of microscopes and showed the boys an *Amœba* and a number of *Foraminifera* and *Radiolaria*. They all bring notebooks, and Mr. Ashton requires them to write out, afterwards, an account of each lesson. Next week I shall take animal cells, so that they may understand something of the structure of the various animal tissues. Then I shall take each group of Invertebrates in ascending order."

This ought to do good to the boys and help the school. It is a small beginning in that general intro-

*From Queen's College, Cork.

duction of the methods and results of science to the rising generation which is so desirable in the interests of national progress.

CURATOR'S REPORT.

Mr. Chadwick reports to me as follows:—

“ I again have the pleasure of recording an increase in the number of researchers and students who have resorted to our laboratories, the total number this year being sixty. The Universities and other institutions represented were almost the same as those of last year, with the addition of Queen's College, Cork, and the Technical School, Huddersfield. Of the sixty workers, forty-two occupied tables at the one time, during the Easter vacation; and, in spite of the increased accommodation afforded by the new research laboratory, it was found necessary to utilise the museum gallery in order to avoid overcrowding and its attendant inconveniences.

“ The weather during the Spring vacation was, on the whole, favourable for out-door work, and much shore-collecting was done under the guidance of Professor Herdman, Professor Harvey Gibson, Professor Cole, Dr. Dakin and Mr. W. A. Gunn. Several visits were paid, by boat from Port St. Mary, to the caves in the neighbourhood of the Sugar Loaf Rock, and were greatly appreciated by the senior students who participated in the exceptional opportunities of collecting afforded by these expeditions. In addition to the practical instruction given in the laboratories during the day, evening lectures were given by Dr. Dakin, on ‘Plankton,’ and by the Curator, who gave an account of his studies on the local Echinoderm larvae, illustrated by a large series of lantern slides photographed from his own original drawings.

“The various branches of the work of the Station, including the collection and preservation twice a week of Plankton gatherings in the bay, have been carried on successfully throughout the year. The collections have been forwarded periodically to Mr. Andrew Scott to be examined in connection with Professor Herdman’s ‘Intensive Study of the Plankton.’

“About a year ago Mr. G. H. Wailes, who is completing the Monograph on the British Freshwater Rhizopoda begun by the late Mr. James Cash and published by the Ray Society, asked me to send him samples of damp moss from water courses and boggy places in the neighbourhood of Port Erin. I did this, and Mr. Wailes has kindly supplied the subjoined list of Rhizopoda and Desmidiaceæ found in a quantity of moss from the little cascade which falls over the cliff close to the old harbour workshops. Very little is known of the freshwater Rhizopoda of the Isle of Man, and the list of species found by Mr. Wailes seems to indicate a promising field of research.

RHIZOPODA.

LOBOSA.	FILOSA.
<i>Arcella vulgaris</i> .	<i>Euglypha alveolata</i> .
„ „ var. <i>gibbosa</i> .	„ <i>laevis</i> .
„ <i>discoïdes</i> .	„ „ , with apical spines.
<i>Centropyxis aculeata</i> .	„ sp. nov.
„ <i>arcelloïdes</i> .	<i>Trinema enchelys</i> .
<i>Diffugia oblonga</i> .	„ <i>lineare</i> .
„ „ var. <i>lacustris</i> .	<i>Cyphoderia ampulla</i> .
„ <i>globulus</i> .	„ „ var. <i>major</i> .
„ <i>constricta</i> .	„ „ other varieties.
„ <i>pristis</i> .	<i>Sphenoderia dentata</i> .
„ <i>lucida</i> .	<i>Pamphagus hyalinus</i> .
„ <i>rubescens</i> .	
<i>Pontigulasia compressa</i> .	
„ <i>bryophila</i> .	
<i>Pyxidicula operculata</i> .	
<i>Quadrula symmetrica</i> .	
„ <i>irregularis</i> .	
<i>Heleopera petricola</i> .	

DESMIDIACEÆ.

<i>Cosmarium speciosum</i> .	<i>Cosmarium laeve</i> .
„ <i>formulosum</i> .	„ <i>Botrutis</i> .

“The number of visitors to the Aquarium during the year—13,200—shows a slight but gratifying increase compared with last year. No exceptionally large attendances on single days were recorded, but the daily average attendance improved substantially towards the end of the season. The number of copies of the ‘Guide to the Aquarium’ sold—over 700—again shows a considerable increase, and bears testimony to the well-sustained interest of the more intelligent visitors. A new edition will be required during the coming year, and is now in preparation.

“Visits have been paid to the Station by the Douglas Progressive Debating Society and the Douglas Sunday School Teachers’ Association, in addition to seven visits of parties of boys and girls from local and other insular elementary schools. The Curator was present on all occasions, and generally gave a short illustrated lecture in addition to an explanation of the contents of the tanks. The Station was visited in July last by MM. Docteur Armand Geoffrey, Médecin de la Marine, and Robert Cayrol, Enseigne de Vaisseau, Boulogne-sur-Mer; and in September by Professor E. W. MacBride, F.R.S. On September 14th a meeting of the Isle of Man Natural History and Antiquarian Society took place at the Biological Station. The chair was occupied by the Deemster Callow, Chairman of the Fishery Board, and an address was given by Professor Herdman on ‘Science in relation to the prosperity of nations, and the need of a more wide-spread education in the methods of science.’

“Owing to the comparatively small number of adult plaice in the spawning pond during the hatching season, the number of fry set free in the neighbouring seas was considerably less than that of last year. Favoured by the comparative absence of boisterous winds, the pond

was thoroughly skimmed by the Assistant Curator on forty-five of the fifty-eight days over which the season lasted. The largest number of eggs obtained on one day was 356,000 on April 15th, but collections of over 300,000 were made on three previous days. The total number for the season was 7,462,000, and the total number of fry set free in the sea was 4,929,600. The majority of the young fish were liberated by Professor Herdman from his yacht 'Runa,' at a distance of about five miles from land.

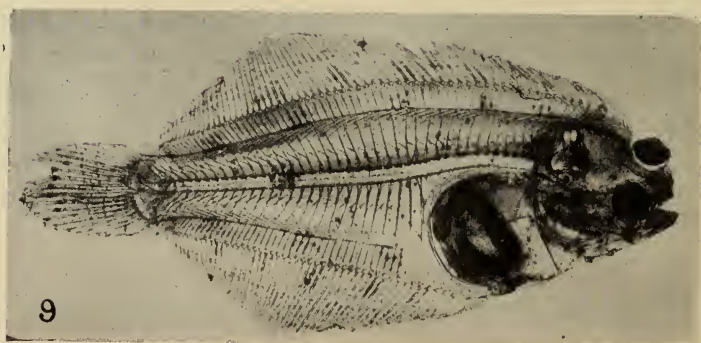
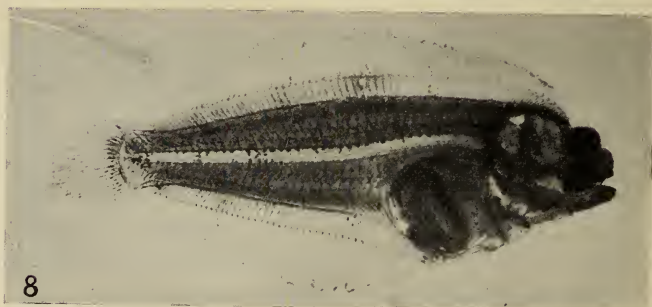
" Figures 4 to 9 show a series of stages in the development of the young plaice from the newly hatched larva (4) through the post-larval metamorphosis (5 to 8) to the young flat-fish (9). They are from photographs taken at Port Erin by Dr. Francis Ward.

" The numbers of plaice eggs collected and of larvae set free during the past season were as follows:—

Eggs collected.	Date.	Larvæ set free.	Date.
121,800 ...	March 2	90,300 ...	March 21
135,400 ...	" 3	166,400 ...	" 21
59,800 ...	" 4	47,200 ...	" 21
108,000 ...	" 6	85,000 ...	" 21
187,000 ...	" 7	135,500 ...	" 30
116,500 ...	" 8	91,300 ...	" 30
169,000 ...	" 10	135,500 ...	" 30
125,000 ...	" 11	101,000 ...	" 30
191,000 ...	" 13	164,700 ...	April 4
192,250 ...	" 14	164,000 ...	" 4
99,700 ...	" 15	79,700 ...	" 7
174,300 ...	" 16	139,700 ...	" 7
159,600 ...	" 18	117,000 ...	" 11
199,500 ...	" 20	168,000 ...	" 11
176,400 ...	" 21	139,700 ...	" 12
203,800 ...	" 22	162,700 ...	" 12
175,300 ...	" 23	140,700 ...	" 13
198,500 ...	" 24	147,000 ...	" 13
135,500 ...	" 25	90,000 ...	" 15
202,600 ...	" 27	156,400 ...	" 15
188,000 ...	" 29	137,200 ...	" 17
312,900 ...	" 30	241,300 ...	" 18

Eggs collected.	Date.	Larvæ set free.	Date.
347,000 ...	March 31	220,000 ...	April 22
143,800 ...	April 1	94,500 ...	„ 22
315,000 ...	„ 3	220,000 ...	„ 22
235,200 ...	„ 4	160,000 ...	„ 22
219,000 ...	„ 5	137,000 ...	„ 22
179,500 ...	„ 6	112,000 ...	„ 24
195,300 ...	„ 7	136,500 ...	„ 24
195,000 ...	„ 8	124,000 ...	„ 24
216,300 ...	„ 10	132,000 ...	May 1
197,400 ...	„ 11	96,000 ...	„ 1
174,300 ...	„ 12	90,000 ...	„ 1
140,700 ...	„ 13	72,500 ...	„ 1
356,200 ...	„ 15	150,500 ...	„ 1
233,000 ...	„ 17	89,300 ...	„ 6
129,000 ...	„ 18	50,000 ...	„ 6
137,500 ...	„ 19	61,000 ...	„ 6
72,500 ...	„ 20	20,000 ...	„ 6
141,700 ...	„ 21	57,700 ...	„ 6
84,000 ...	„ 22	29,400 ...	„ 15
82,000 ...	„ 24	24,300 ...	„ 15
16,800 ...	„ 26 }	2,000 ...	„ 15
19,000 ...	„ 28 }		
<hr/> 7,462,000 <hr/>		<hr/> 4,929,600 <hr/>	

“ When the plaice hatching season was over (fig. 10), the Curator turned his attention to lobster culture, and by great and persistent effort over twenty ‘berried’ female lobsters with eggs in various stages of ripeness were acquired from local fishermen. The eggs of one of these began to hatch out on June 21st, and experiments in rearing were at once begun, while some of the larvae in the first stage were set free at points where it was thought that suitable ‘cover’ would be found. Altogether 7,450 larvae were hatched, and every effort was made, by experiment on old and new lines, to rear them through their early stages, but without tangible success. All the difficulties of past years were experienced, and it is now abundantly clear that the



propensity of the berried lobsters to shed their ripening eggs cannot be obviated when they are confined in small tanks. The same conditions appear to apply to the health of the larvae. Of 1,400 larvae placed in the large concrete tank in the hatchery only six reached the lobsterling stage; while a considerable percentage of 900 placed in the spawning pond were seen swimming at or near the surface until the third (and in a few cases the fourth) larval stage was reached. Many of these would probably have reached the lobsterling

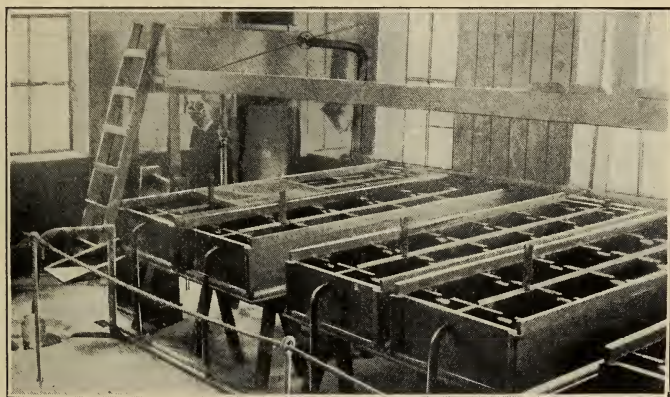


FIG. 10.—The Hatching Tanks when used for rearing lobsters in the Summer.

stage but for the presence of the fish in the pond. It is, no doubt, probable also that the abnormally high temperature to which the water in the pond was raised on many days in July and August by the exceptional heat of the sun this summer had a prejudicial effect on the lobster larvae. It is a curious fact that all our experiments in lobster rearing in this and past years have afforded striking illustrations of the 'survival of

the fittest.' Whenever some hundreds of larvae are confined together in the comparatively small space of a tank, about 2 per cent. or 3 per cent. only reach the lobsterling stage. It apparently matters not whether they are artificially fed or left to exercise their cannibalistic propensities—the result is in all cases practically



FIG. 11. Newly-hatched young lobster. From a photograph by Mr. Edwin Thompson.

the same. No difference in the rate of mortality at the periods of larval ecdysis has been observed between artificially fed larvae and those which have lived entirely upon their weaker brethren. The mortality at the periods of ecdysis was exceedingly heavy amongst the 1,400 larvae in the hatchery tank, though they were fed at frequent intervals and supplied with abundance of circulating water."

OTHER REPORTS ON WORK.

Professor Harvey Gibson writes as follows:—

“ During the Easter vacation a course on Marine Algæ was given at the Station, attended by over twenty advanced students from the Botanical Department of the University, by two students from the University of Birmingham, three from University College, Cork, and one from the University of Cambridge. The course consisted in systematic collecting in Port Erin Bay, Port St. Mary, and elsewhere. The plants collected were examined in the laboratory during flood tide, and each evening a short lecture was given on the morphology and life-history of representative forms. In addition to the identification of species already recorded from the district, several new forms were found and material was gathered for subsequent research. It is hoped at an early date to publish in the ‘Transactions of the Biological Society’ some notes upon these new species, and on certain morphological points which have not hitherto been described. One hundred and fifty-seven species in all were collected, among which the following are the more important novelties:—

CHLOROPHYCEAE.

Prasiola stipitata.
Enteromorpha percursa.
Endoderma witrockii.
Epicladia flustrae.
Cladophora nuda.
Bryopsis hypnoides.

PHAEOPHYCEAE.

Ectocarpus granulosus.
 „ *hincksii*.
Cladostephus verticillatus.
Ascocyclus leclancheri.
Leathesia difformis.
Sporochnus pedunculatus.
Fucus ceranoides.

RHODOPHYCEAE.

Bangia fuscopurpurea.
Helminthocladia purpurea.
Callophyllis laciniata.
Catenella opuntia.
Sphaerococcus coronopifolius.
Champia parvula.
Delesseria hypoglossum.
Ceramium gracillimum.
 „ *acanthonotum*

Dilsea edulis.
Petrocelis cruenta.
Peyssonnelia dubyi.
Hildenbrandtia rosea.
Rhodomela lycopodioides.
Laurentia obtusa.
Polysiphonia violacea.
 „ *byssoides*.
Nemalion multifidum.

“Some of the above were collected by Miss M. Knight, B.Sc., and Miss H. Coburn, B.Sc., at Peel during the Summer vacation.”

During July and August Dr. H. E. Roaf investigated the effect of the concentration of oxygen and free carbon dioxide on the rhythmical movements of marine organisms. He writes as follows:—“The object was to find out if these movements, like those of mammalian respiration, were mainly influenced by the partial pressure of carbon dioxide and not appreciably affected by the concentration of oxygen. In the event of carbon dioxide exercising the main influence, it was further desirable to discover if this effect were due to an increase of acidity or to the increased partial pressure of carbon dioxide. The experiments were carried out by measuring the rate of the rhythmical movements of rock barnacles (*Balanus balanoides*) and the rate of the gill movements of a small fish (*Cottus scorpius*) under different conditions. The results for barnacles suggest that the lower the oxygen concentration the slower are the movements, and with carbon dioxide increasing concentration makes the movements more sluggish. With the fish the reverse holds, namely, that the low concentrations of oxygen and high concentrations of carbon dioxide both increase the rate of movement. The influence of oxygen, however, is so slight that it approaches the limit of experimental error. In both cases the action of carbon dioxide was due to the increase of acidity (hydrogen ion) with increased concentration of carbon dioxide. It is hoped to publish full details of this investigation and its results in a short time.”

Dr. Tattersall, of Manchester University, reports:—

“During the Easter vacation I spent a fortnight at the Port Erin Biological Station, in a further attempt to

rear the eggs of the periwinkle (*Littorina littorea*) through the various stages of their development. Very little success attended my efforts, and I made no progress with the work. I hope to renew the attempt next spring. I am able to add one species of Crustacea to the Port Erin list and to the L.M.B.C. district. On April 11th last, four specimens of *Schistomysis arenosa*, G. O. Sars, were taken in a small hand dredge dragged lightly over the surface of the sand in the centre of the bay. This species is known from the Clyde area, from several places on the Devonshire coast, and from Blacksod Bay in the West of Ireland. As its name implies, the species normally lives buried in fine sand."

Professor Benjamin Moore and Mr. Edward Whitley were engaged during the Easter vacation upon an enquiry into the bio-chemistry of the reproductive organs of *Echinus*, which was continued by Professor Moore during the summer months, and a large amount of material was accumulated and extracted in addition to the work actually carried through at the Port Erin Station. This material is now being utilised in the Bio-Chemical Laboratory at the University of Liverpool for the study of two distinct problems in metabolism by Mr. N. G. S. Coppin, B.Sc., and by Mr. Alfred Adams, M.B., Ch.B.

Professor Moore reports:—

"At the outset the purpose of the research was to discover whether the reproductive organs of *Echinus esculentus* contained any of those more simple representatives of the protein classes, termed protamines and histones, found by Miescher, Kossell and others in the sperm of fishes, and by Matthews in another form of echinoderm. A body closely resembling the arbacin of Matthews was isolated and its properties studied both at Port Erin and later at Liverpool.

“ The primary object in obtaining such bodies which possess strongly alkaline or basic properties, was to test whether they acted as stimulants to cell-division, following up the previous work at the Port Erin laboratory of Moore, Roaf and Whitley a few years ago. In this respect we were disappointed, the histone isolated being found to have no exciting or accelerating action on the speed of division in the fertilised *Echinus* egg. But, at the same time, the physico-chemical properties of this body have been found very interesting. The osmotic properties and pressures developed by its solutions have been studied, and it has been shown to pass into true solution with a high osmotic pressure, demonstrating that these simpler proteins really do possess a less complex molecule.

“ While this work was in progress it was observed that the gonads, both male and female, were very rich in fats, which were incidentally removed as a preliminary to obtaining the protamines and histones. Also, it was noticed that a batch of gonads obtained from *Echini* which had been kept for about a week without added food in the tanks, apparently yielded less oil on extraction than the gonads of specimens taken fresh from the sea.

“ This suggested the idea that the gonads, in addition to their more obvious function, might also act as metabolic organs, like the hepato-pancreas of molluscs and arthropods, or the liver of mammals. It was, therefore, determined to study the chemistry of the gonads at different seasons of the year, and especially to estimate the nature and amount of metabolic products, such as fats and glycogen present at different times.

“ With this object in view batches of *Echini* were assembled in August and September. Some lots were

killed and the gonads extracted in the fresh condition, others were kept fed in the tanks and the gonads extracted, and still others were kept for a period without food and then killed and the gonads extracted.

“So much can already be said that, so far from representing an exhausted gland at this time of year, the gonads in both sexes are as large as in the breeding season and contain both fats and glycogen in large amounts. The glycogen content is being investigated by Mr. Coppin, while Mr. Adams is determining the nature and amount of the fats.

“One important point to be determined is whether the amount of metabolic material stored up varies with the state of nutrition, and whether such variations occur apart from the breeding season.”

Mr. W. Riddell, M.A., was at work at Port Erin during both the Easter and the summer vacations, assisting me with the Plankton investigation; but in the intervals of that work he took up one or two other matters. He continued his systematic work on the Polychaeta of the neighbourhood, and to the list given in last report he has been able to add *Nereis virens*, *Glycera siphonostoma* and *Notophyllum foliosum*, the latter dredged off Dalby in September, 1911. Mr. Riddell also commenced an investigation into the nature of the disease which has been causing much damage to the plaice in the spawning pond during the last few years, but this work has hardly been carried far enough as yet to warrant any definite statement.

Dr. W. J. Dakin reports to me as follows on his research work:—

“During the Easter vacation I continued some of the osmotic pressure experiments commenced at Helgoland. These experiments had shown that the

blood of teleosts from the aquarium tanks had a lower osmotic pressure than blood from freshly-caught (living) fish from the sea. There was a possibility that this difference might be due, in an indirect manner, to differences in hydrostatic pressure. In order to determine the factor bringing about the abnormal constitution of the aquarium fish, a number of living plaice were taken out to sea in the 'Runa,' and half were lowered in a perforated box to the bottom in about 20 fathoms of water, whilst the remainder were kept at the surface in a floating box. Full details of the methods employed will appear in the paper (to be published in the 'Internationale Revue d. Hydrobiologie'). The osmotic pressure of the blood from both the batches of fish was found to be identical. Evidently, therefore, differences in hydrostatic pressure are not responsible for the differences previously observed in the blood, and other aquarium conditions must be examined in order to find the cause of the abnormalities.

"In connection with my work on the Whelk (*Buccinum undatum*), which was continued at Port Erin both in the Easter vacation and during September, some details may be of interest. It has already been shown that one can almost always be certain of finding stages of an interesting Coccidian parasite in the renal organ, and that for class work this may be regarded as a good example of a Sporozoon easily obtained. Another parasite occurs in the stomach and rectum—namely, an endo-parasitic Turbellarian (*Graffia buccinicola*). As almost every whelk appears to be infected and contains on an average about a dozen specimens, this may also be taken as a convenient type for laboratory teaching purposes. It is particularly valuable, since endo-parasitic Turbellaria are by no means common. The

parasite was discovered in Port Erin whelks fourteen years ago, by Jameson, and it does not seem to have been recorded elsewhere. It is interesting to find it turning up still in the same place. Jameson states that it occurs in the kidney and kidney duct, but those that I have found were always in the stomach and rectum. As the kidney opens directly to the exterior I cannot quite understand what Jameson meant by kidney duct.

“Most of the detailed work on the anatomy of the whelk has now been completed, and I hope to have the MS. ready for publication in January.”

During part of the Easter vacation Miss M. Latarche, B.Sc., made a preliminary bio-metrical investigation of the variation in the shells of the common limpet (*Patella vulgata*). These were taken from three different localities, viz.:—Port Erin, Fleshwick Bay and Port St. Mary.

Comparisons were made between sets of shells taken—

- (1) From high and low water marks;
- (2) From Carboniferous limestone and Cambrian slate;
- (3) From more exposed and more sheltered waters.

The variation occurred chiefly in the height of the cone compared with the breadth. The shells of those taken from about low-water mark were found to be much flatter than those taken from near high-water mark.

The nature of the rock on which the *Patellae* lived did not affect the height of the shells. Those found on the limestone at Port St. Mary were more markedly ridged and were of a lighter colour. Intermediate links between these and the darker, smoother, shells of Port Erin were found to exist in both localities.

Contrary to expectation there was no difference in height between shells taken from the more exposed and the more sheltered places, if taken at the same water level. The two sides of the Port Erin breakwater served as splendid collecting grounds for material for this purpose.

Mr. H. G. Jackson, B.Sc., in addition to giving me some assistance in taking the observations and plankton gatherings at sea during the Easter vacation, started an investigation of the complete anatomy and histology of *Pagurus bernhardus*, the Hermit Crab. Mr. Jackson is now continuing that work during the winter in the Liverpool Laboratory, and the results will be published, when completed, as an L.M.B.C. Memoir.

Professor F. J. Cole, with two members of the Staff, Mr. H. L. Hawkins and Mr. A. H. Malpas, and three of his senior students from University College, Reading, worked at Port Erin during the Easter vacation. Professor Cole writes to me, as follows, in regard to their work:—

“The visit to Port Erin, last Easter, of our College party of six was partly for educational and partly for collecting purposes. The College has now provided for the Easter class in the estimates, so that it will now become an annual event. Its importance and popularity with the students are too manifest to be dwelt upon, and we expect to have a larger party working at the Station next Easter. We were able this year to add two species to the local fauna—*Nereis virens*, from Port Erin Bay, and a peculiar Rhizocephalon, related to *Peltogaster*, but still undetermined, which was found parasitic on a large *Galathea*. We brought back a quantity of material for the Museum, including a number of successful injections of Echinoderms, *Eledone* and Fishes.”

PLANKTON INVESTIGATION.

These observations have been carried on in much the same way as in the previous four years, with the kind help of various Assistants; and the new yacht (S.Y. "Runa," 95 tons, see fig. 12) has proved most satisfactory, and very comfortable for work at sea.



FIG. 12. Prof. Herdman's fishing-yacht "Runa," from a photograph taken by Dr. C. Macalister, at Shetland, on August 10th, 1911.

During the Easter and the Summer vacations Mr. Riddell and Mr. H. G. Jackson helped me in the observations on board the yacht, Mr. Chadwick did some of the work of preserving the catches on shore and also supervised the collections made from the bay during the remainder of the year, and Mr. Andrew Scott is now examining all the gatherings in detail with the microscope.

Altogether 119 samples were collected at sea from the yacht in the Easter vacation, and 84 in the latter part of August and in September [in the earlier part of the

summer vacation I was engaged in taking observations further North, off the West Coast of Scotland]; while about 150 gatherings were obtained from the bay during the remainder of the year.

The year has been a somewhat unusual one in weather, and that may have had some effect upon the plankton. The material has not yet all been examined, and it is still too early to make any very definite statement, but the following provisional remarks, giving the impressions formed at the time of collecting, may be of some interest:—

In April, at Port Erin, *Biddulphia* and *Coscinodiscus* were well represented, and also *Chaetoceras decipiens* and *C. teres*.

At Piel, in the Barrow Channel, Mr. Scott tells me, between April 15th and 19th, the plankton was very rich in *Chaetoceras* and *Rhizosolenia*, and a few *Thalassiosira nordenskioldi* were noticed early in March, but this and some other typical spring Diatoms, such as *Lauderia* did not occur in any quantity at Port Erin this Easter. *Noctiluca* was still living in the sea at Port Erin up to the end of January, an unusual circumstance due, perhaps, to the mild winter.

May 13th.—The vernal Diatoms now appeared in quantities at Port Erin (calm weather with a marked rise in temperature).

May 16th.—Tow-net gatherings large, and consisted almost entirely of Diatoms (weather continues calm and the increase in temperature is maintained).

May 19th.—Diatoms occurred in very large quantities, especially in the fine net.

May 22nd.—Catches rather smaller, but Diatoms still in abundance, even in the vertical net (weather still fine and warm).

May 25th.—Diatoms much less numerous. Fine net had only about one-tenth, or less, of the gatherings on 19th (no obvious change in weather conditions).

All the above large catches of Diatoms consisted almost entirely of *Chaetoceras*. It was not until a week later that *Rhizosolenia* (fig. 13) made its appearance. It reached its maximum early in June, and then gradually died off. By the beginning of July the Diatoms had practically disappeared.



FIG. 13. Diatom Plankton, consisting mainly of *Rhizosolenia semispina*.



FIG. 14. Copepod Plankton, consisting wholly of *Calanus helgolandicus*.

I insert here a short list just received from Mr. A. Scott, giving the quantity of plankton and his estimate of the total number of Diatoms present in each

haul of the fine net, taken during the month of the Diatom maximum.

Date.		Quantity in c.c.		Total Diatoms.
May	1	...	2.5	43,360
,,	4	...	1.0	10,610
,,	10	...	6.5	525,680
,,	13	...	30.2	19,118,000
,,	16	...	60.2	54,141,500
,,	19	...	54.5	34,447,500
,,	22	...	30.5	27,775,000
,,	25	...	8.3	2,504,500
,,	29	...	14.8	22,023,100
June	1	...	11.3	4,620,000
,,	3	...	24.7	13,132,000
,,	5	...	12.7	2,143,000

On July 5th Port Erin Bay was invaded by an exceptional swarm of the Copepod *Calanus helgolandicus* (fig. 14), such as for some years now has always appeared for a few days about this part of the summer. In 1909 there was an enormous *Calanus* swarm on July 17th to 19th.

After being absent or rare during July, August and most of September Diatoms made their appearance again, for the Autumn visitation, towards the end of September, and were very abundant in all the gatherings during the first week of October. They continued to be present in quantity during October, the high numbers keeping up longer than usual. Both species of *Biddulphia* (*B. mobiliensis* and *B. sinensis*, see fig. 15) occurred in quantity in October, and occasionally in September, an unusually early appearance for *B. sinensis*, which seems to be in very vigorous condition this year. Readers may be reminded that this is the species from the Far East, which made its appearance in European seas eight years ago, and is rapidly spreading along our

coasts. Fig. 16 shows the two species of *Biddulphia* under a higher magnification.

Our *B. mobiliensis* (Fig. 16, *a*) approaches the form "*regia*" regarded as a distinct though allied species by



FIG. 15. Plankton showing *Biddulphia sinensis* and *B. mobiliensis*.

Ostenfeld. *B. sinensis* (Fig. 16, *b*) seems to be of more elongated form in our district than in Ostenfeld's figures.

The autumnal Diatoms finally disappeared at the end of October, and since then the plankton has remained relatively small in quantity. A detailed account of the plankton catches of the year will, as usual, be given by Mr. Andrew Scott and myself in the Lancashire Sea-Fisheries Laboratory Report, early in 1912. We may remark here, however, that the figures given above, for May, are unusually large, and that the increase from

the ten thousand on May 4th to over fifty-four millions on May 16th, is most rapid. The most abundant species were *Chaetoceras debile* and *Ch. sociale*. On May 16th



FIG. 16. *Biddulphia mobiliensis* (a) and *B. sinensis* (b).

the first of these species reached thirty millions and the second 12 millions in the standard fifteen minutes' haul with a small net one foot in diameter of mouth.

EXTENDED INVESTIGATION UP THE WEST COAST.

In last year's report I pointed out that our knowledge of the minute floating life or "plankton" of the western coasts of the British Islands was very incomplete because of a great gap extending from the North of Scotland down to the Irish Sea—a gap which neither the International Observations, on the one hand, nor those of the Scottish and the Irish Authorities, on the other, seem to fill up.

With a view to obtaining some data that may, in part at least, bridge this gap, and possibly throw light

upon the causes of the seasonal changes in the plankton of the Irish Sea, for several years back, during the summer vacation, I have taken plankton hauls, both vertical and horizontal, from the yacht at many localities amongst the islands and lochs of the West of Scotland, as far north as Portree in Skye, and as far out to the west as the island of Barra. I was able to show



FIG. 17. Zooplankton.



FIG. 18. Phytoplankton.

in the last report, from these Scottish gatherings, that the state of affairs at that time of year is somewhat different from that in the Irish Sea. At some spots in Hebridean Seas, for example, very large Phyto-plankton hauls may be taken year after year in July—at a time when in Manx waters the hauls are for the most part comparatively small, and are all composed of Zoo-plankton (figs. 17 and 18).

During this last summer (July and August, 1911) I devoted a longer time than usual to a more detailed survey, with both bottom and surface nets, of a considerable area off the West and North of Scotland. The larger yacht we now have available for such work renders it possible to go further, take a larger party and remain out longer. Mr. Wm. Riddell acted as my Assistant on part of the cruise, and will help in working up the details of the material collected for a later report. I can only at present give a brief preliminary account of the results obtained. Our observations extend from the Irish Sea as far North as Noup of Noss in Shetland (from 54° N. lat. to 60° N. lat.) and as far West as Castle Bay in Barra. They include 152 observations of the sea-temperature, and 142 of the salinity. On August 22nd, when crossing from the south end of Cantyre to the North of Ireland, a series of nine temperature and salinity observations were taken, one every hour during the most important part of the traverse; and on the following day when crossing from Larne in Ireland to Port Erin, another series of eleven hourly observations was taken. During these two months (July 7th to August 23rd) the temperatures varied from 11.2° C. to 17.8° C., and salinities from 1.018 ($= 22.69 \text{ ‰}$) to 1.0276 ($= 34.87 \text{ ‰}$), the latter reading being a very high salinity for British seas. It was recorded on August 12th in the open sea to the East of the Shetlands, but nearly as high a reading was obtained off Fair Island, off North Ronaldsay and elsewhere in the Orkney seas, and 1.027 was obtained on July 13th and 14th, off Canna and Rum on the West of Scotland.

It would be premature, until the samples have been more fully investigated, to make any positive statements as to how this year's observations compare with those

of previous summers; but this much may be said that the impression produced at the time of collecting (fig. 19) was that during July and August the Diatoms were less in evidence, that the Phyto-plankton was less in amount



FIG. 19. Taking Plankton and Salinity observations on the "Runa."

and less widely extended, and that a larger proportion of the present collection is Zoo-planktonic.

In addition to the investigation of the plankton a certain amount of dredging with the "Agassiz" trawl (see fig. 20) took place during the Scottish cruise. The apparatus worked well, and some interesting hauls were obtained. Figure 21 gives the appearance of a mixed

haul of Invertebrates when emptied on the deck. Probably our most interesting capture with the dredge was the Giant Sea-Pen (*Funiculina quadrangularis*, which was recorded* as follows in a letter which was sent to "Nature" from the "Runa" on July 11th:—

"Marine Biologists may be interested to hear that



FIG. 20. S. Y. "Runa" with the "Agassiz" dredge coming up at the stern.

the bed, near Oban, of the largest British Pennatulid *Funiculina quadrangularis*, and the smaller *Virgularia mirabilis* described by Mr. W. P. Marshall and the late Professor Milnes Marshall, in 1881 or 1882 (I have no books of reference with me), is still apparently in very flourishing condition. In a couple of hauls of the small Agassiz trawl, from this yacht yesterday, between the islands of Kerrera and Lismore, at depths of eighteen to twenty fathoms, I got about a dozen fine specimens of

Funiculina, the largest of which measured nearly four feet in length. The bed must be of considerable extent, as the hauls were not on the same spot, and both brought up equally good specimens of these magnificent pennatulids. Most of the large specimens of Funiculina,



FIG. 21. Examining the Catch on deck.

by the way, were not caught in the trawl-net, but were balanced across the front of the frame, at each end, in such a precarious position as to make one wonder how many others had been lost in hauling in. The bottom deposit was evidently fine mud."

THE MICROSCOPIC LIFE OF THE BEACH.

An immense amount of work remains to be done in examining with the microscope the various deposits, such as sand and mud, found between tide-marks on our shores—not once for all, but periodically; so as to determine the nature of the minute animals and plants, their relative abundance and their variations in quantity. Some of these lowly organisms, although individually insignificant, may exist in such quantities as to discolour the sands or the sea-water, and even give rise to plagues amongst shell-fish and other more valuable animals. Invasions of this kind are known to have appeared in America and in Australia, and a minute animal, hitherto unnoticed in British seas, has been found repeatedly on the tidal sands at Port Erin this year in considerable quantity. I gave a preliminary account of this occurrence to the Linnean Society of London on June 1st, and described the later manifestations at the Portsmouth meeting of the British Association in September. As there have been some further changes since, I shall now summarise the whole visitation, quoting some parts from what was published by the Linnean Society in their *Journal*,* and using, by kind permission of the Society, the blocks which were prepared for that publication. The matter began with the following observation:—

“In going to and fro between the village of Port Erin and the Biological Station, during the recent Easter vacation, those of us who were constantly at work had occasion to take a short cut across the sandy beach at least twice and sometimes six times in the day. One gets into the habit, in these traverses, of looking closely at the beach when the tide is out, on the chance of seeing something of interest cast up. On April 7th, I noticed a

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new and somewhat unusual appearance on the sand about or a little above half-tide mark. The hollows of the ripple-marks and other slight depressions formed by the water draining off the beach were occupied or outlined by a greenish-brown deposit which in places extended on to the level parts so as to discolour patches of the sand (see fig. 22).

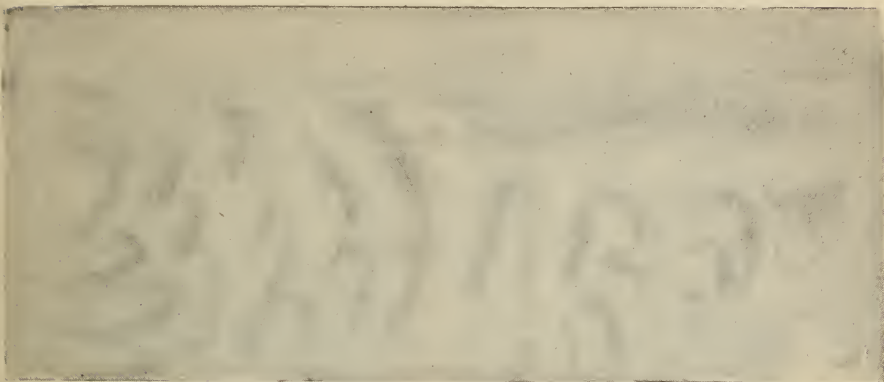


Fig. 22. The general appearance of the brown deposits in the ripple-marks on the sand, reduced in size.

“ In this position the deposit remained, more or less, for a month—waxing and waning, sometimes increasing in a tide, say, roughly tenfold, and at other times apparently disappearing for a day or two and then re-appearing either on the same part of the beach, or it might be a few hundred yards away. At one time it discoloured a continuous stretch of sand about fifty yards long by five yards in breadth a little below high-water mark, and was noticeable from some distance away.

“ On first noticing it I supposed the appearance was caused by a deposit of Diatoms, but on taking a sample to the laboratory, microscopic examination showed that although a few Diatoms (including *Navicula amphisbaena*, or a closely allied form) were present, the

deposit was formed almost wholly of enormous numbers of a very active little Peridinian or Dinoflagellate of a bright yellow colour (figs. 23 and 24). More careful investigation, in which Mr. Riddell and Miss M. Lata arche helped me, enabled us to identify this form as *Amphidinium operculatum*, described by Claparède and Lachmann, in 1858, from specimens obtained at Christiansand, Bergen, and a few other places in Norway.



Fig. 23. Sand-grains and *Amphidinium* (photo-micrograph under low-power magnification).

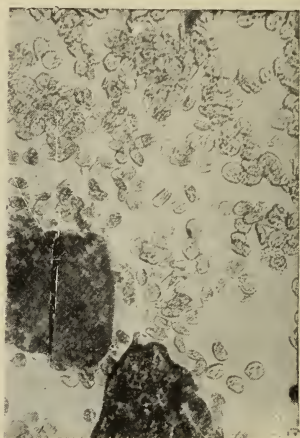


Fig. 24. Part of Fig. 23 under high-power magnification.

“The published records of *Amphidinium*, however, do not give the impression that it is a common or abundant organism. The latest comprehensive work on such forms—the article on Peridiniales, by Paulsen, in the ‘Nordisches Plankton’ (Kiel, 1908)—recognises four species of *Amphidinium*: *A. crassum*, *A. rotundatum*, and *A. longum*, which as yet have been recorded from Kiel only; and *A. operculatum*, which is stated to occur in brackish water on the north coasts of Europe. In

addition, Kofoid ('Dinoflagellata of the San Diego Region,' 1907) records *A. lacustre* from fresh water, *A. aculeatum*, a pelagic form from Naples, and *A. sulcatum*, which he took in a vertical haul from ninety fathoms in the Pacific. On hunting through the few scattered references to *A. operculatum* which occur, one finds, however, that R. S. Bergh, in the 'Zoologischer Anzeiger' for 1882, states (p. 693) that Spengel in December and January found it in huge quantities on the beach at Norderney. Although, therefore, *Amphidinium operculatum* has been recorded once before as occurring in quantity, the occurrence appears to be a sufficiently rare event to be worthy of notice; and, so far as I can ascertain, the species, although known from several parts of North-west Europe, has not been previously found on the British coasts. I have written to most of the marine laboratories (Plymouth, Cullercoats, St. Andrews, and Millport) and to many marine biologists, and have not been able to hear of any British record.

"It is, however, not an unknown thing for rare Dinoflagellates to appear suddenly in some locality on an occasion in phenomenal quantities. Torrey, in the 'American Naturalist' for 1902, describes the unusual occurrence of a species of *Gonyaulax* on the coast of California. Sherwood and Vinal Edwards, in the 'Bulletin of the United States Bureau of Fisheries' for 1901, tell how for two weeks in September a *Peridinium* infested Narragansett Bay in such numbers as to colour the water blood-red and cause the death of many fishes. Finally, Whitelegge, in the 'Records of the Australian Museum' for 1891, gives an interesting account of a new species of *Glenodinium* (*G. rubrum*) which appeared in such quantities in Port Jackson as to give the water 'the

appearance of blood' and cause the death of great numbers of oysters, mussels, and all forms of shore life. Whitelegge supposed that the very heavy rainfall that year, by affecting the salinity of the water, and then a lengthened period of calm weather which followed, may have provided favourable conditions for an unusual development of the Dinoflagellata. The *Glenodinium* appeared in vast numbers about the middle of March and disappeared early in May. When it was at its climax, the allied colourless species *Gymnodinium spirale* appeared in the bay and soon increased greatly in numbers and became finally even more abundant than the red *Glenodinium* upon which it was evidently feeding.

“Returning now to our *Amphidinium operculatum*, it is not easy to account for the sudden appearance of this unusual Dinoflagellate (previously unrecorded in Britain) in such profusion on the beach at Port Erin last April. Plankton hauls were being taken regularly across the bay at the time, and they showed no trace of the organism. In fact, *Amphidinium* has not occurred in any of the thousands of gatherings which we have taken in the Irish Sea during the last five years, and which have been examined in minute detail by Mr. Andrew Scott.

“Thinking it might be present in the shallow water close to the edge of the beach, Mr. W. Riddell and I took some hauls of the tow-net from a punt worked backwards and forwards in a few inches of water as near as we could get to the discoloured sand, but the gathering, although it contained fine sand and mud, showed no trace of our Dinoflagellate. It may be noted here that although the size of the *Amphidinium*, 0·05 mm. in greatest diameter, is such that it can slip through the mesh (averaging about 0·08 mm.) of the finest

plankton silk (No. 20), still so much clogging of the meshes always takes place in such hauls, and so many other smaller organisms and particles of mud are retained, that it is certain that had the *Amphidinium* been present in any quantity in the water it would have shown up in the gatherings.

“Careful scraping of the sand showed that the Dinoflagellates were only in and on the surface-layer, and therefore could not be regarded as coming up from below. It occurred to us that possibly they might be fresh-water forms derived from the land; but we ascertained that the little stream in the centre of the bay, which in wet weather overflows on to the beach (at other times it is conveyed into the town sewer), had not, on account of the unusually dry season, sent any water to the beach for some weeks. Moreover, on experimenting with the living *Amphidinium* in the laboratory, Miss Latache found that while it lived well in sea-water, or when diluted with a little fresh, it died at once in fresh and survived for a few days only in brackish water, containing only a little sea-water. The exact salinities of these mixtures were, unfortunately, not noted at the time. Samples of the *Amphidinium* kept in shallow dishes of wet sand at the Biological Station in a few days showed such profuse growth that the sand was covered by a dark-coloured layer, the water became impure, and eventually all the Dinoflagellates died off.

“Observation under the microscope shows that although this is a singularly active Dinoflagellate, circling round and round with great vigour, so that a drop of sand and water containing a number of the organisms presents a most animated picture under a low power magnification, still the *Amphidinium* seems to be actually attracted to the sand-grains and associated with

them. The sand-grains in the field of view are always peppered over with a number of specimens of the *Amphidinium* (figs. 23, 24, 25), and if individuals be watched they are seen after swimming round to come back to rest on a sand-grain and remain there for a time before starting off on another excursion. If they are thus constantly associated with sand-grains or other solid particles, and never swim more than a microscopic distance from such a resting-place, that may account for the fact that we have never found them in our plankton gatherings.

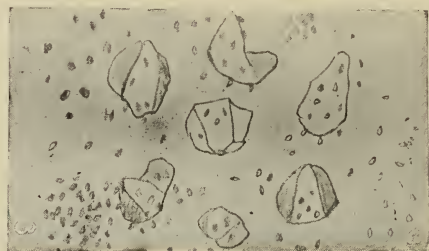


Fig. 25. Sketch from living preparation, to show some *Amphidinia* resting on the sand-grains and others swimming about (low power).

“*Amphidinium operculatum* is also, however, positively heliotropic, congregating in quantity on the lighter side of the dish in the laboratory, and shifting in bulk from the sand at the darker part of a tank to the end nearer the window. This property accounts for the invariable occurrence of the discoloured sand on the surface only and never in the deeper layers.

“The published figures of this species are not very good, so a view of both dorsal and ventral surfaces, as seen under a high magnification, is given here (fig. 26). There certainly seems to be a slight but definite cuticle covering the greater part of the surface, although this

has been denied by some previous writers. The two characteristic Dinoflagellate grooves certainly join, as is stated by Calkins, but not by other observers. The posterior flagellum which projects freely from the body is not difficult to see, but the anterior one which lies along the transverse groove is not so easy to demonstrate, and may differ a little in position and extent from what is shown in the figure. Stages in longitudinal fission were frequently seen, and that is probably the commonest method of reproduction. What appeared to be conjugation between two individuals was observed by Miss Lata arche in one instance.

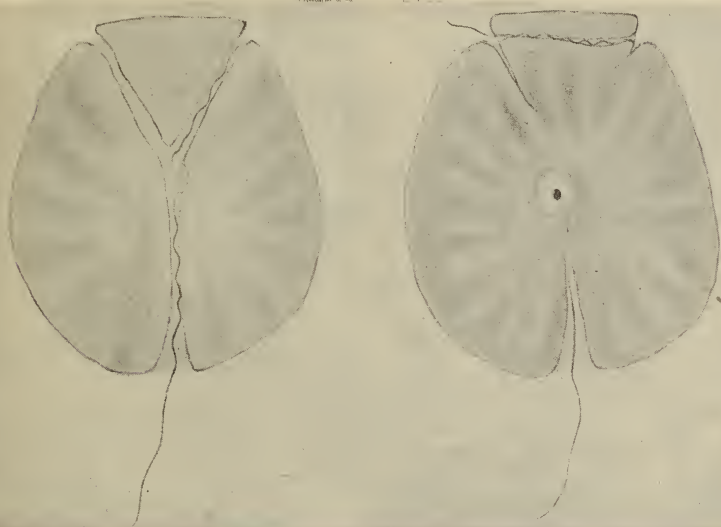


Fig. 26. Dorsal and ventral views of *Amphidinium operculatum*—enlarged from high-power magnification.

“It may be that this organism lives normally in small quantities, so as not to be conspicuous, in some region of the sandy beach, or possibly in some special

habitat beyond the beach, and that the present vast increase in numbers has been due to some unusual conjunction of circumstances; but what these were I am not yet prepared to suggest. Several possible explanations have occurred to us which we hope to test by further observation. In the case of the Port Jackson *Glenodinium* plague, Whitelegge thought the increase may have been due to exceptional rainfall and calm weather; but the occurrence this spring at Port Erin was preceded by unusually dry and rather stormy weather."

When giving this account of the matter to the Linnean Society, on June 1st, I concluded by saying:—"I am inclined to think that, although I can find no previous record of such an occurrence, it is probable that these swarms of *Amphidinium* have been seen before at Port Erin, and possibly elsewhere. I fancy I have seen the phenomenon myself in the past, and have supposed it to be due to swarms of Diatoms, which certainly do cause some of the yellowish-green and brownish-green patches on the sand between tide-marks."

Two days after making this statement I was again on the beach at Port Erin. I found in the same region what was apparently the same patch of discoloured sand, but on examining a scraping with the microscope found that the deposit was now wholly composed of a golden-yellow Naviculoid Diatom—one of the "*Amphisbaena* group" of *Navicula* (fig. 27), probably *Navicula* (*Caloneis*) *amphisbaena*, Bory. I searched the beach carefully between tide-marks, and examined samples from every suspected patch of sand, but could find no trace of *Amphidinium*. The *Navicula*, which was present in April in very small quantity (see above), seemed to have completely replaced the Dinoflagellate. We have probably still much to learn in regard to the comings and

goings of such microscopic forms and their physiological inter-relations in connection with what may be called "the metabolism of the beach."

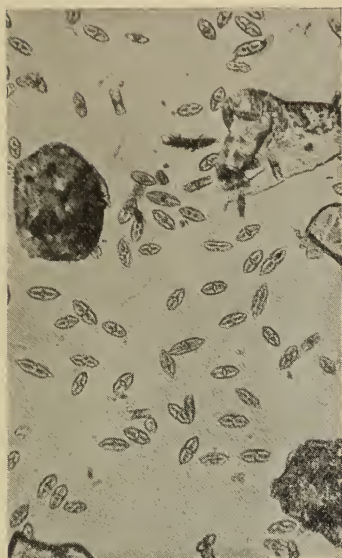


FIG. 27. *Navicula amphisbaena*. (?)

FIG. 28. *Navicula digito-radiata*. (?)

For the photo-micrographs reproduced as Figures 13 to 18, 23, 24, 27 and 28, we are indebted to our Hon. Treasurer, Mr. Edwin Thompson.

The Diatoms—both *Navicula* "*amphisbaena*" and another more slender form (fig. 28), very similar to *Navicula digito-radiata* (Greg.), along with a few specimens of a larger form, apparently a species of *Pleurosigma*—remained in possession of the beach during most of June and July, and no trace of the Dinoflagellates was seen for about four months. But on returning to Port Erin, on September 9th, after the meeting of the British Association at Portsmouth, where I had made a statement as to the April *Amphidinium* having been replaced

by the June *Navicula*, I found to my surprise that the brown patches on the sand were once more present, and now showed dense swarms of *Amphidinium*, but no Diatoms. This condition remained for a few days, and then disappeared, and on the 16th the Naviculoid Diatoms were back again in force and remained abundant during the 17th and 18th of September. On the last two dates some small and rather greener patches were found which on examination proved to consist of a bright green Euglenoid Infusorian. The *Amphidinia* made their appearance next on October 2nd, and remained more or less in evidence during the month. They were in great abundance on the 12th and 13th, again on the 19th, and finally, on the 25th and 26th. No *Amphidinia* were found between October 28th and November 1st, but on November 2nd some small patches again made their appearance in the usual positions on the beach and then died away.

The following may be given as a brief tabular statement of these remarkable alternations of the animal (*Amphidinium*) and the plant (Diatoms) on the beach at Port Erin during these seven months in 1911.

April 7 to May 1	...	Amphidinium, and a few Diatoms (<i>Navicula</i>)
June 3 to July 22	...	Diatoms (some <i>Navicula</i> , others <i>Pleurosigma</i>)
Sept. 9 and 10	...	Amphidinium in abundance, Diatoms absent
Sept. 16 to 18	...	Diatoms (naviculoid)
Oct. 2 to 26	...	Amphidinium in abundance, Diatoms absent
Oct. 28 to Nov. 1	...	No Amphidinium present
November 2	...	Amphidinium (3 small patches)

Since this date neither organism has been found, and no brown patches have been seen on the sand.

Presented in this form the evident alternation between these two kinds of organism is very striking, and, although it may be impossible as yet to give any full explanation, still the facts seem to point to the probability that the cause of the phenomenon is a physiological one and that the explanation may consist in showing that each organism in turn in its metabolism

exhausts or alters some essential constituent of the environment so as to prevent its own continued existence, in quantity, at that spot, but leaves the ground suitable, or even favourable, to the physiological needs of the other set of competing organisms.

L.M.B.C. MEMOIRS.

No further Memoirs since No. XIX, *POLYCHÆT LARVÆ* (the young stages of the Higher Worms) at Port Erin, by Mr. F. H. Gravely, M.Sc., have been published. *BUCCINUM*, the large whelk, by Dr. W. J. Dakin; and *PAGURUS*, the Hermit Crab, by Mr. H. G. Jackson, will be ready for publication this winter; while *DORIS*, the Sea-lemon, by Sir Charles Eliot; *SAGITTA*, the Arrow-worm, by Mr. Harvey; *SABELLARIA*, a tube-building Annelid, by Mr. A. T. Watson, and other Memoirs are also far advanced; and we hope to have a Memoir on our Irish Sea Species of *Ceratium* and other *Dinoflagellata* from Professor C. A. Kofoed, who did some work on the local material during his visit to our laboratory in 1908.

The following shows a list of the Memoirs already published or arranged for:

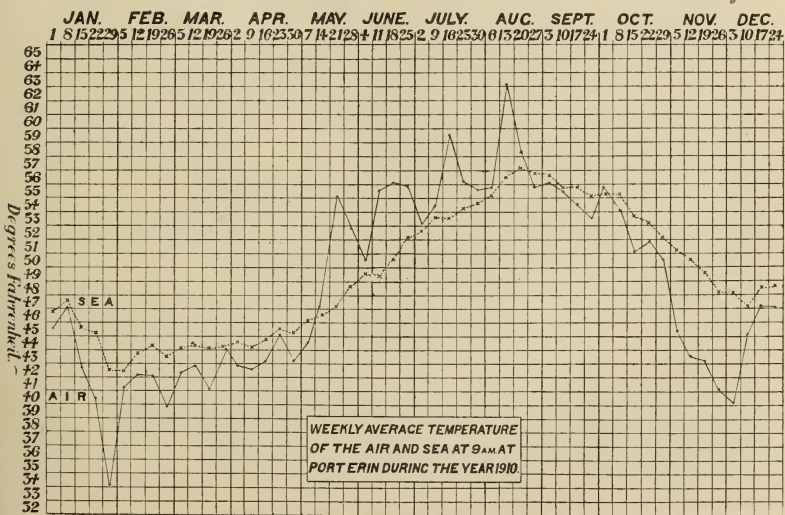
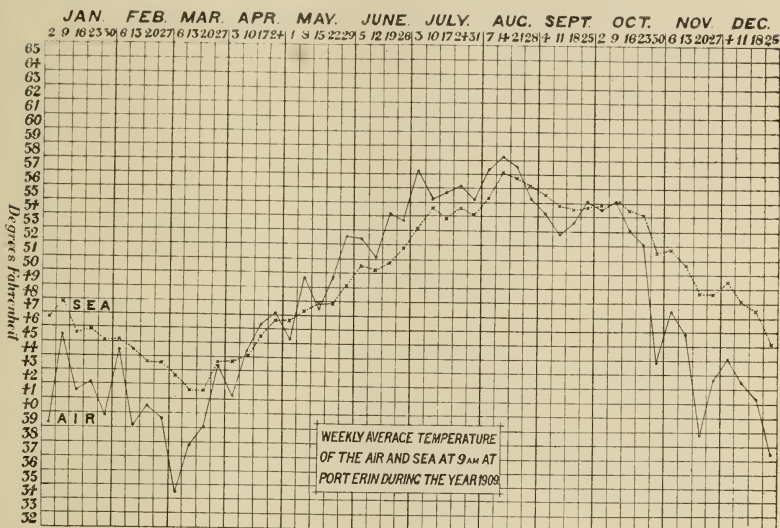
- I. *ASCIDIA*, W. A. Herdman, 60 pp., 5 Pls.
- II. *CARDIUM*, J. Johnstone, 92 pp., 7 Pls.
- III. *ECHINUS*, H. C. Chadwick, 36 pp., 5 Pls.
- IV. *CODIUM*, R. J. H. Gibson and H. Auld, 3 Pls.
- V. *ALCYONIUM*, S. J. Hickson, 30 pp., 3 Pls.
- VI. *LEPEOPHTHEIRUS* AND *LERNÆA*, A. Scott, 5 Pls.
- VII. *LINEUS*, R. C. Punnett, 40 pp., 4 Pls.
- VIII. *PLAICE*, F. J. Cole and J. Johnstone, 11 Pls.
- IX. *CHONDRUS*, O. V. Darbishire, 50 pp., 7 Pls.
- X. *PATELLA*, J. R. A. Davis and H. J. Fleure, 4 Pls.
- XI. *ARENICOLA*, J. H. Ashworth, 126 pp., 8 Pls.
- XII. *GAMMARUS*, M. Cussans, 55 pp., 4 Pls.
- XIII. *ANURIDA*, A. D. Imms, 107 pp., 8 Pls.
- XIV. *LIGIA*, C. G. Hewitt, 45 pp., 4 Pls.

- XV. ANTEDON, H. C. Chadwick, 55 pp., 7 Pls.
 XVI. CANCER, J. Pearson, 217 pp., 13 Pls.
 XVII. PECTEN, W. J. Dakin, 144 pp., 9 Pls.
 XVIII. ELEDONE, A. Isgrove, 113 pp., 10 Pls.
 XIX. POLYCHAET LARVÆ, F. H. Gravely, 79 pp., 4 Pls.
 XX. BUCCINUM, W. J. Dakin.
 XXI. PAGURUS, H. G. Jackson.
 DORIS, Sir Charles Eliot.
 SABELLARIA, A. T. Watson.
 SAGITTA, E. J. W. Harvey.
 CUCUMARIA, E. Hindle.
 OYSTER, W. A. Herdman and J. T. Jenkins.
 OSTRACOD (CYTHERE), Andrew Scott.
 BUGULA, Laura R. Thornely.
 HIMANTHALIA, F. J. Lewis.
 DIATOMS, F. E. Weiss.
 FUCUS, J. B. Farmer.
 BOTRYLLOIDES, W. A. Herdman.
 ACTINIA, J. A. Clubb.
 HYDROID, E. T. Browne.
 HALICHONDRIA AND SYCON, A. Dendy.

In addition to these, other Memoirs will be arranged for, on suitable types, such as *Pontobdella*, a Cestode and a Pycnogonid.

In addition to what can be recorded in this Annual Report, there are some pieces of work which are incomplete, or only begun, and there are many isolated observations being accumulated. Moreover, there are Mr. Chadwick's routine daily records of the physical conditions of sea and air which may sometime prove of interest in connection with plankton results and with variations in the Fisheries. The diagram of Sea and Air Temperatures for 1911 is not yet completed, but those for the two preceding years (which have not

previously appeared in our Reports) are inserted here to show the general similarity of the two curves, along with a few points of divergence, and the manner in which the temperature of the sea lags behind that of the air in both winter and summer.



We append to this Report:—

- (A) The usual Statement as to the constitution of the L.M.B.C., and the Laboratory Regulations;
- (B) The Hon. Treasurer's Report, List of Subscribers, and Balance Sheet.

APPENDIX A.

THE LIVERPOOL MARINE BIOLOGY
COMMITTEE (1911).

HIS EXCELLENCY THE RIGHT HON. LORD RAGLAN, Lieut.-Governor of the Isle of Man.

RT. HON. SIR JOHN BRUNNER, BART.

PROF. R. J. HARVEY GIBSON, M.A., F.L.S., Liverpool.

MR. W. J. HALLS, Liverpool.

PROF. W.A. HERDMAN, D.Sc., F.R.S., F.L.S., Liverpool.
Chairman of the L.M.B.C., and Hon. Director of the Biological Station.

MR. P. M. C. KERMODE, Ramsey, Isle of Man.

PROF. BENJAMIN MOORE, Liverpool.

SIR CHARLES PETRIE, Liverpool.

MR. E. THOMPSON, Liverpool, Hon. Treasurer.

MR. A. O. WALKER, F.L.S., J.P., formerly of Chester.

MR. ARNOLD T. WATSON, F.L.S., Sheffield.

Curator of the Station—MR. H. C. CHADWICK, A.L.S.

Assistant—MR. T. N. CREGEEN.

CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The OBJECT of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea and, if practicable, to establish and maintain a Biological Station on some convenient part of the coast.

II.—The COMMITTEE shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the AFFAIRS of the Committee shall be conducted by an HON. DIRECTOR, who shall be Chairman of the Committee, and an HON. TREASURER, both of whom shall be appointed at the Annual Meeting, and shall be eligible for re-election.

IV.—Any VACANCIES on the Committee, caused by death or resignation, shall be filled by the election at the Annual Meeting, of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The EXPENSES of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who, for this purpose, shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The BIOLOGICAL STATION shall be used primarily for the Exploring work of the Committee, and the SPECIMENS collected shall, so far as is necessary, be

placed in the first instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

LIVERPOOL MARINE BIOLOGICAL STATION

AT

PORT ERIN.

LABORATORY REGULATIONS.

I.—This Biological Station is under the control of the Liverpool Marine Biological Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. E. Thompson).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator (Mr. H. C. Chadwick), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus, &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and

Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the Committee.

V.—Those who are entitled to work in the Station, when there is room, and after formal application to the Director, are:—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges. Institutions, such as Universities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the

Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed by the Committee, the specimens obtained on these occasions must be retained by the Committee (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to lay a paper on some of his results—or at least a short report upon his work—before the Biological Society of Liverpool during the current or the following session.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to Professor Herdman, F.R.S., University, Liverpool.

APPENDIX B.

HON. TREASURER'S STATEMENT.

In the following pages the Annual Subscription List and Balance Sheet are shown.

Unfortunately the List of Subscribers is slightly less than last year, which is much to be regretted, as the expenses become greater year by year owing to the increased work done at Port Erin.

The Balance Sheet shows a small balance in hand, but next year the expenses will be extremely heavy owing to the publication of two new Memoirs, and more funds for this purpose are badly needed.

EDWIN THOMPSON,
Hon. Treasurer.

25, Sefton Drive,
Liverpool.

SUBSCRIBERS.

	£	s.	d.
Beaumont, W. I., Citadel Hill, Plymouth ...	1	1	0
Briscoe, F. W., Colby, Isle of Man	0	10	6
Browne, Edward T., B.A., Anglefield, Berkhamsted, Herts.	1	1	0
Boyce, the late Sir Rubert, F.R.S., University, Liverpool	1	1	0
Brunner, Mond & Co., Northwich... ..	1	1	0
Brunner, Rt. Hon. Sir John, Bart., Silverlands, Chertsey	5	0	0
Brunner, J. F. L., M.P., 23, Weatherley Gardens, London, S.W.	2	2	0
Brunner, Roscoe, Belmont Hall, Northwich ...	1	1	0
Bullen, Rev. R. Ashington, Heathside-road, Woking	1	1	0
Caton, Dr., 78, Rodney-street, Liverpool	1	1	0
Clubb, Dr. J. A., Public Museums, Liverpool ...	0	10	6
Cole, Prof., University College, Reading	1	1	0
Crellin, John C., J.P., Andreas, I. of Man... ..	0	10	0
Crosfield, Harold G., Oxtou, Birkenhead	1	1	0
Dale, Sir Alfred, University, Liverpool	1	1	0
Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescott ...	2	2	0
Eliot, Sir Charles, University, Sheffield	1	1	0
Graveley, F. H., Indian Museum, Calcutta	0	10	6
Halls, W. J., 35, Lord-street, Liverpool	1	1	0
Herdman, Prof., F.R.S., University, Liverpool ...	2	2	0
Hewitt, David B., J.P., Northwich	1	1	0
Hickson, Prof., F.R.S., University, Manchester ...	1	1	0
Holland, Walter, Carnatic Hall, Mossley Hill ...	1	1	0
Holt, the late Alfred, Crofton, Aigburth, Liverpool	2	2	0
Holt, Dr. Alfred, Crofton, Aigburth, Liverpool ...	1	0	0
Holt, Mrs., Sudley, Mossley Hill, Liverpool ...	2	2	0
Holt, P. H., Croxteth-gate, Sefton-park, Liverpool	1	1	0
Isle of Man Natural History Society	2	2	0

Forward £37 9 6

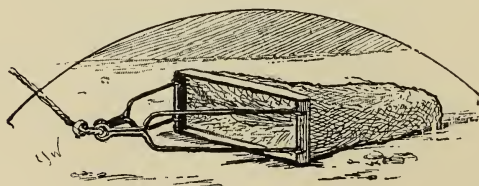
	£	s.	d.
Forward...	37	9	6
Jarmay, Gustav, Hartford, Cheshire ...	1	1	0
Lever, Sir W. H., Thornton Hough, Cheshire ...	1	1	0
Lewis, Dr. W. B., W. Riding Asylum, Wakefield...	1	1	0
Livingston, Charles, 16, Brunswick-st., Liverpool	1	1	0
Manchester Microscopical Society... ..	1	1	0
Meade-King, R. R., Tower Buildings, Liverpool...	0	10	0
Mond, R., Sevenoaks, Kent... ..	5	0	0
Monks, F. W., Warrington... ..	2	2	0
Mosley, F. O., Woodside-road, Beaumont Park, Huddersfield	1	1	0
Muspratt, Dr. E. K., Seaforth Hall, Liverpool ...	5	0	0
Narramore, W., Cambridge Avenue, Great Crosby	1	1	0
O'Connell, Dr. J. H., Dunloe, Heathfield-road, Liverpool	1	1	0
Petrie, Sir Charles, Devonshire-road, Liverpool ...	1	1	0
Rae, Edward, Courthill, Birkenhead	1	1	0
Rathbone, Mrs. Theo., Backwood, Neston... ..	1	1	0
Rathbone, Miss May, Northumberland-street, London	1	1	0
Rathbone, Mrs., Green Bank, Allerton, Liverpool	2	0	0
Roberts, Mrs. Isaac, Thomery, S. et M., France ...	1	1	1
Robinson, Miss M. E., Holmfield, Aigburth, L'pool	1	0	0
Smith, A. T., 43, Castle-street, Liverpool... ..	1	1	0
Tate, Sir W. H., Woolton, Liverpool	2	2	0
Thompson & Capper, Manesty-buildings, Liverpool	1	1	0
Thomson, Dr. J. Stuart, University, Manchester	1	1	0
Thornely, Miss, Nunclose, Grassendale	0	10	0
Thornely, Miss L. R., Nunclose, Grassendale ...	2	2	0
Toll, J. M., 49, Newsham-drive, Liverpool	1	1	0
Walker, Alfred O., Ulcombe Place, Maidstone ...	3	3	0
Watson, A. T., Tapton-crescent Road, Sheffield ...	1	1	0
Whitley, Edward, Oxford	2	2	0

Forward £81 18 7

	£	s.	d.
Forward	81	18	7
Weiss, Prof. F. E., University, Manchester ...	1	1	0
Wiglesworth, Dr., Rainhill... ..	1	1	0
Wragg, Sir W., D.C.L., Port St. Mary, Isle of Man	1	1	0
Yates, Harry, 75, Shudehill, Manchester ...	1	1	0
	<hr/>		
	£86	2	7
<i>Deduct</i> Subscriptions still unpaid, <i>less</i> old			
Subscriptions received	9	9	0
	<hr/>		
	£76	13	7
	<hr/>		

SUBSCRIPTIONS FOR THE HIRE OF "WORK-TABLES."

Victoria University, Manchester	£10	0	0
University, Liverpool	10	0	0
University, Birmingham	10	0	0
Bedford College for Women, London	2	2	0
University College, Reading	2	2	0
	<hr/>		
	£34	4	0
	<hr/>		



The Naturalist's Dredge.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr.

IN ACCOUNT WITH EDWIN THOMPSON, HON. TREASURER.

Cr.

1910.	£	s.	d.
To Printing and Stationery	9	2	2
" Printing 1910 Report	13	11	9
" Boat Hire	6	14	0
" Books and Apparatus at Port Erin Biological Station	42	13	4
" Postage, Carriage, &c.	6	6	8
" Natural History Specimens.....	0	1	0
" Salary—Share of Curator's.....	75	0	0
" " Assistant's	27	6	0
" Sundries	9	5	0
" Amount transferred to Memoir Fund	30	0	0
" Balance in hand December, 1911	0	14	9
	<u>£220</u>	<u>14</u>	<u>8</u>

EDWIN THOMPSON,

HON. TREASURER.

LIVERPOOL, December 15th, 1911.

1910.	£	s.	d.
By Balance in hand December, 1910	12	4	3
" Subscriptions and Donations received	76	13	7
" Amount received from Universities for hire of " Work Tables "	34	4	0
" Sale of Specimens, Bottles, &c.	1	17	10
" Interest on British Association (1896) Fund ..	37	13	4
" Bank Interest.....	6	7	5
" Laboratory and Glass Fees	4	10	6
" Sale of Guides.....	8	15	3
" Admissions to Aquarium, Share of.....	28	9	6
" Sale of Memoirs	8	8	0
" " Post Cards	0	18	0
" Botany Class	0	13	0
	<u>£220</u>	<u>14</u>	<u>8</u>

Endowed Invested Fund:—

British Workman's Public House Co. 39 Shares

£1 each fully paid.

Memoir Fund—Balance in Bank £179 6 0

Extension Fund:—

Balance, December, 1910.....

Deduct Payments during year 1911 354 3 0

312 18 9

£41 4 3

Audited and found correct,

COOK & LEATHER,
Chartered Accountants.

REPORT on the INVESTIGATIONS carried on during 1911
in connection with the LANCASHIRE SEA-FISHERIES
LABORATORY at the University of Liverpool, and
the SEA-FISH HATCHERY at Piel, near Barrow.

Drawn up by Professor W. A. HERDMAN, F.R.S., Honorary
Director of the Scientific Work; assisted by Mr.
ANDREW SCOTT, A.L.S., Resident Fisheries Assistant
at Piel; and Mr. JAMES JOHNSTONE, B.Sc., Fisheries
Assistant at the Liverpool Laboratory; and others.

(With plates and text figures.)

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INTRODUCTION.

The account of the hatching of edible flat fish (plaice and flounders) at our Piel establishment, the details of which are given by Mr. Scott in the body of this Report, shows that the work has proceeded on the normal lines and has resulted, as usual, in about thirteen and a quarter millions of young fish having been set free in the Lancashire waters. To these have to be added the

millions set free from the Port Erin Hatchery when considering the Irish Sea as a whole. Care is taken in the distribution from both hatcheries to return the fry to the sea in suitable localities, such as are frequented by the naturally produced fish of the same age. I desire to point out, however, that these numbers must be regarded as small, though it is difficult to see how, with our present accommodation and organisation, they could be substantially increased.

Mr. Scott also gives particulars of the practical classes in Marine Biology and in Navigation for fishermen, and in Nature Study for school teachers, held in the Piel Laboratory by Mr. Johnstone and himself during Spring and early Summer.

Dr. Bassett, who for several years has kindly undertaken the examination of the samples of sea-water obtained in our hydrographic cruises, has now been appointed Professor of Chemistry in University College, Reading, but I am glad to say that he still continues to carry on our work, and his report on the results obtained during 1911 will be found printed below.

A great series of valuable statistics in regard to the measurements of plaice, caught in the course of the routine trawling experiments carried out by Captain Wignall and the other Fishery Officers of the district, is now being accumulated. An instalment of these, bringing the matter up to date, is given by Mr. Johnstone, but no general discussion of these data will be attempted until a sufficient series has been accumulated to render the conclusions independent of annual variations. Mr. Johnstone, however, makes use of some of these statistics as the basis for a short note on the formula dealing with the relation of length to weight in the plaice. This will be found at page 86.

FISH PARASITES AND FISH DISEASES.

Mr. Johnstone has an important article dealing with certain new internal parasites of common fishes in the district, and also with various diseased conditions in the Ray, the Cod and the Flounder, which have been investigated in the Laboratory during the year. All these points are rather technical and cannot be briefly summarised, but they all add important items to our knowledge of the conditions under which our fish live. A further paper on a similar subject, viz., a diseased condition which affects the spawning Plaice in the hatchery ponds at Port Erin, is given by Mr. W. Riddell and Dr. Alexander, and the Bacteria found in the diseased fish are discussed.

BACTERIOLOGY OF SHELL-FISH BEDS.

The shell-fish question in its relation to Public Health is becoming of increasing importance, almost year by year. Mr. Johnstone, who carries out our bacteriological investigations, has had further work in connection with the Conway Mussel beds during the past year, and has just made a report to the Fishery Board for Scotland on the topographical and bacteriological condition of the Oyster beds in the Firth of Forth, near Edinburgh. On account of the growing importance of this work, and the prospects of its increase in the near future, I have thought it useful to give in the present Report a summary and discussion of the bacteriological investigations that have been undertaken in the past under the direction of the Committee, and to point out how necessary it is that the topographical relations of the samples examined in the laboratory should be studied by the naturalist in the field. Tides and other currents,

prevalent winds, shelter, depth of water, nature of bottom and condition of the shell-fish bed, all affect the distribution of the sewage and other organisms; and the Bacteriologist who undertakes such work, unless he is a Field-Naturalist and Fisheries expert and knows how to allow for the various factors in the environment, runs considerable risk of being deceived by the samples examined and of arriving at erroneous conclusions as to the condition of the shell-fish in relation to sewage contamination.

PLANKTON INVESTIGATIONS.

Mr. Riddell and I have undertaken for a second year a discussion of the plankton samples which I collected from my yacht in the seas to the North and West of our district. This year our cruise in July and August extended from the Irish Sea to the Shetland Islands, so we were able to sample undoubted Atlantic water of high salinity bringing in Oceanic organisms. The relations of the Oceanic water and its living contents to the periodic changes and variations in the plankton of our coastal waters are not easy to unravel, and our occasional collecting expeditions to the Scottish waters north of this district are undertaken in the hope of throwing light on the distribution of the plankton organisms and their history throughout the year.

My investigations, with Mr. Andrew Scott, of the plankton collected in the Irish Sea throughout the year have followed the usual lines and are reported upon in "Intensive Study," Part V, in the same manner as before. The work is of such a detailed nature that no brief statement in regard to it can be usefully made.

FISHERIES EXHIBITION.

It was decided last Summer to arrange an Exhibition illustrative of the fisheries of the district, and a grant of money was made by the Committee in August for this purpose. Most of the specimens required had already been collected for the Fisheries Museum at Liverpool University. Otherwise it would have been impossible to have obtained them in the time at our disposal. Work connected with this Fisheries Exhibit occupied a large part of Mr. Johnstone's and Mr. Scott's time during the Summer. Dr. Jenkins took pains to obtain for us some fine specimens which were needed to complete the series. My private Research-Assistant, Mr. Wm. Riddell, also gave a good deal of time and valuable assistance in the preparation of specimens, illustrations and labels for this Exhibition.

I desire, however, to put on record for the information of the Committee that, although a number of different minds and hands have co-operated in the preparations, this Fisheries Exhibition is mainly the work of Mr. Johnstone, who has been indefatigable in his efforts to obtain the best specimens and illustrations and to arrange them in the most instructive manner.

In order to make the Exhibition more complete we have had to include, on loan, some series (such as samples of sea-bottoms, and of Plankton gatherings) that belong to the Zoological Museum of the University, and some results of work done at the Port Erin Biological Station and elsewhere on the West Coast.

The collection was sent in the first instance, at the request of the Fishmongers' Company and the National Sea Fisheries Protection Association, to the Fisheries Exhibition which was held in the Autumn at Rusholme,

Manchester. After that it was removed to the Public Museum in Liverpool, where for some weeks it occupied a very favourable position in the middle of one of the large galleries, close to the Museum collection of British Fishes; and there it was seen to great advantage and was apparently much appreciated by the Liverpool public. A special descriptive Guide with many illustrations was prepared in order to put before the public the extent of the Lancashire Sea Fisheries District, the Committee's administrative and scientific organisation, the nature of their work, and some of their results. A number of copies of this Guide were sold during the Liverpool visit. In December the Exhibition was removed to the Art Gallery at Oldham, and about the middle of January it was taken to the Chadwick Museum at Bolton. It is now on the point of being moved to Preston, and arrangements have been made for visits thereafter to several of the other Lancashire boroughs.

This summary-exposition, as our travelling Exhibit may be called, of the application of science to sea-fisheries investigation in our district ought to focus attention upon what has been done during recent years under the auspices of the Lancashire and Western Sea-Fisheries Committee, and should help in educating public opinion as to the claims of such work for recognition and substantial support.

The delay in receiving any response to the Committee's application to the Treasury for a grant in aid of such work, under the Development Act, has been most disappointing and, from the point of view of the scientific staff, almost disastrous. We are aware that the delay has not been caused at the Treasury, nor by the Development Commissioners. The pity is that during all this time useful work remains undone for want of funds,

which we understand are waiting to be used; series of observations at sea, which were stopped pending the receipt of support from Government, cannot yet be resumed, and the break in our records becomes monthly more serious and may at some future time prove a fatal obstacle to the completeness and validity of important conclusions. In the interests of fishery research on the West Coast, it is devoutly to be hoped that the subsidy recommended by the Commissioners to the Committee's application may enable our full scheme of observations and experiments to be resumed at an early date. It is understood that the Commission has reported favourably on our claims and that the answer from the Treasury may now be received any day. We have suffered so much from delay which we have been powerless to avert, that it may be hoped that we shall now set an example to others by promptly organising our scheme of work and expenditure, in the event of an adequate grant being placed at our disposal.*

I have placed as an Appendix, at the end of this Report, a detailed memoir on the Edible Whelk (*Buccinum undatum*), prepared by Dr. W. J. Dakin, of the Zoology department in the University of Liverpool. The Whelk is of economic importance, both as a food-matter and as a fisherman's bait, and I am sure that Fisheries Authorities and investigators will be glad to have placed before them in this accessible form all the information in regard to the animal's structure, actions, life-history and value that has been brought together by Dr. Dakin.

W. A. HERDMAN.

FISHERIES LABORATORY,

UNIVERSITY OF LIVERPOOL:

March 25th, 1912.

* *In Press*, May 1st, 1912.—Since the above was printed notification of a grant of £1,640 for the current year has been received, and the new scheme of investigation under the Development Act has now started. W.A.H.

FISH HATCHING AT PIEL.

By ANDREW SCOTT, A.L.S.

The results from the fish hatching carried on in the spring of 1911 were almost similar to those obtained in previous years. The adult plaice were trawled in the autumn of 1910 in the closed area of Luce Bay by our Fisheries steamer, and we have again to thank the Fishery Board of Scotland for the necessary permission to fish in this protected fishing ground. The flounders were caught in the vicinity of Piel by the police cutter stationed in the Northern section of the Lancashire district.

Unfertilised eggs from plaice and flounders were noticed floating in the tanks for the first time on February 26th. Fertilised eggs from both species of fish were collected and placed in the hatching boxes ten days later. The spawning was earlier in 1911 than in 1910, and was no doubt accelerated by the mildness of the winter. Spawning at sea also appeared to be earlier in 1911 than in the previous year, as many of the whiting caught by the steamer on the off-shore fishing grounds near Morecambe Bay light-vessel for dissection in the first fishermen's class were quite mature. When the fourth class began on May 8th the fish in the tanks had practically finished spawning, and mature whiting were unobtainable at sea. The spawning of the fish in the tanks lasted two months. During that period fully one and a quarter millions of plaice eggs were obtained, and thirteen and a quarter millions of flounder eggs. The incubation of the eggs was carried out in the Dannevig hatching apparatus, and the resulting fry afterwards liberated in the sea.

The following tables give the number of eggs collected and the fry set free on the dates specified:—

PLAICE (*Pleuronectes platessa*, Linn.).

Eggs Collected.				Fry Set Free.			
March	8	...	20,000	16,000	...	April	3
"	11	...	35,000	30,000	...	"	"
"	14	..	40,000	34,000	...	"	10
"	16	...	55,000	46,500	...	"	"
"	18	...	65,000	57,000	...	"	"
"	20	...	75,000	65,500	...	"	17
"	22	...	80,000	69,500	...	"	"
"	25	...	80,000	69,500	...	"	"
"	28	...	85,000	74,500	...	"	24
"	30	...	90,000	78,500	...	"	"
April	1	...	95,000	83,500	...	"	"
"	4	...	85,000	74,500	...	May	1
"	6	...	80,000	69,500	...	"	"
"	8	...	75,000	65,500	...	"	"
"	11	...	75,000	65,500	...	"	8
"	13	...	65,000	57,000	...	"	"
"	15	...	55,000	46,500	...	"	"
"	18	...	45,000	39,500	...	"	"
"	21	...	30,000	24,500	...	"	18
"	25	...	25,000	20,000	...	"	"
"	29	...	10,000	8,000	...	"	"
May	2	...	6,000	5,000	...	"	"
Total Eggs 1,271,000				1,100,000	Total Fry.		

FLOUNDER (*Pleuronectes flesus*, Linn.).

Eggs Collected.			Fry Set Free.		
March	8	... 200,000	176,000	... March	27
"	11	... 350,000	300,000	... "	"
"	14	... 450,000	388,000	... April	3
"	16	... 650,000	579,500	... "	"
"	18	... 700,000	600,000	... "	"
"	20	... 800,000	710,000	... "	10
"	22	... 850,000	757,000	... "	"
"	25	... 850,000	757,000	... "	"
"	28	... 900,000	800,000	... "	17
"	30	... 900,000	800,000	... "	"
April	1	... 900,000	800,000	... "	"
"	4	... 900,000	800,000	... "	24
"	6	... 850,000	757,000	... "	"
"	8	... 800,000	710,000	... "	"
"	11	... 750,000	662,500	... May	1
"	13	... 700,000	600,000	... "	"
"	15	... 650,000	579,500	... "	"
"	18	... 500,000	442,500	... "	"
"	21	... 450,000	388,000	... "	8
"	25	... 350,000	300,000	... "	"
"	29	... 150,000	132,500	... "	"
May	2	... 80,000	69,500	... "	18
"	5	... 35,000	31,000	... "	"
"	8	... 10,000	8,000	... "	"
Total Eggs <u>13,775,000</u>			<u>12,148,000</u>	Total Fry.	

Total Number of Eggs 15,046,000

Total Number of Fry 13,248,000

CLASSES, VISITORS, &c., AT PIEL.

By ANDREW SCOTT, A.L.S.

Four classes for fishermen were held at Piel in the spring of 1911. The Education Committee of the Lancashire County Council voted the usual sum of money, which enables forty-five fishermen residing in the Administrative area to attend a course of instruction at Piel. The Southport Education Committee sent four men and the Blackpool Education Committee again sent three men. The Liverpool Education Committee sent two fishermen from the steam trawlers fishing out of Liverpool. The Cumberland Education Committee, for the first time, sent men belonging to that county. Altogether, fifty-seven fishermen students attended the classes, and received instruction in Elementary Marine Biology. Twenty-eight of them also received a course of instruction in Navigation and Seamanship in addition to their Marine Biology. The studentship holders were divided into four classes—three of fourteen each, and one of fifteen men, as shown by the following lists:—

First Class, held March 13th to 24th.—J. N. Armstrong, Silloth; John Ferguson, Maryport; John Butler, Flookburgh; James Hill, Flookburgh; Thomas Cocking (Junr.), Morecambe; George Mount, Morecambe; James Cartmell, Blackpool; W. Gornall, Blackpool; Jack Rimmer, Blackpool; Richard Howard, Southport; Benjamin Wright, Southport; John Wright, Southport; William Wright, Southport; Joseph Beck, Liverpool; Frederick Houghton, Liverpool.

Second Class, held March 27th to April 7th.—Thomas Pater, Whitehaven; William Wilson, Bailcliffe; William Hodgson, Flookburgh; Thomas Shaw, Flookburgh;

Thomas Ghorst, Bolton-le-Sands; Arthur Townley, Sunderland Point; Richard Bond, Morecambe; Thomas Bond, Morecambe; Thomas Gerrard, Morecambe; Henry Atkinson, Knott End, Fleetwood; John Abram, Banks; Richard Abram, Banks; Richard Brookfield, Banks; Thomas Abram, Banks.

Third Class, held April 24th to May 5th.—H. Chapple, H. Crompton, R. J. Gornall, J. Harrison, F. Hill, J. Johnson, A. Kissack, T. Nisbett, C. Price, J. Rawcliff, T. Singleton, S. Smith, C. E. Wilson, W. Wright, Fleetwood.

Fourth Class, held May 8th to 19th.—R. Cringle, J. Cropper, R. Grundy, T. Hodgson, W. Holmes, J. Huntington, R. Iddon, M. McMannus, T. Nisbett, W. P. Sawyers, M. Sumner, W. A. Tennant, G. Wright, J. Wright, Fleetwood.

In the first two classes the course of instruction related to Marine Biology only, and was similar to what has been given in former years. The third and fourth classes were restricted to deep sea trawl fishermen, residing in Fleetwood, who were preparing to sit for the Board of Trade examinations for certificates as second hand or skipper of a fishing vessel. The morning lesson, lasting two and a half hours, dealt with Marine Biology suitable for deep sea fishermen. The afternoon lesson, lasting three hours, was conducted by Captain E. Barker Thornber, the County Navigation Instructor, who gave an efficient course in Navigation and Seamanship. The continued success of the Navigation courses has led to further development, and it has been decided to hold three classes for deep sea trawlers in the spring of 1912. Only one class in Marine Biology will be held.

Classes for first and second year courses in Nature Study for school teachers were carried on between April

26th and May 19th. These classes were again organised by the Barrow Education Committee, with the permission of the Chairman of the Sea-Fisheries Scientific Sub-Committee.

The annual inspection of the classes by the Members of the Sea-Fisheries Committee, and of the various Education Committees of the County, was arranged to take place on May 3rd. The day proved most unfavourable. The party were unable to land from the steamer after she arrived in the harbour, owing to a strong southerly gale and heavy sea beating on the shore. A number of representatives of the steam trawling industry at Fleetwood visited the class on May 11th, and were able to see the men at work. Members of various rambling clubs and a party of scholars from Barrow Secondary School visited the establishment on the Saturday afternoons during March and April. Mr. A. Harris, H.M. Inspector of evening schools for the district paid an official visit, and inspected the teaching work that was going on. Mr. K. C. Dé, of the Indian Civil Service, came to see the laboratory, along with Dr. Jenkins, in July. Dr. J. W. Robertson, Chairman of the Royal Commission on Industrial Training and Technical Education, Canada, paid a visit to the establishment in September. He made exhaustive enquiries regarding the methods employed at Piel in carrying on the classes for the instruction of fishermen in Navigation and Elementary Marine Biology, and the Nature Study (Marine Life) Classes for school teachers. The equipment of the establishment was inspected, and favourably commented upon. Mr. T. Kitahara, of the Imperial Bureau of Fisheries, Japan, also called and made inquiries about the work carried on. The following letter has recently been received from the Director, Department of Technical Education, Province of Nova

Scotia, Canada. “Will you kindly send me a full and
“detailed outline of the classes which you give in life
“history of fish, etc., for the special instruction of men
“engaged in the fishing industry. I note that you give
“the only class in England dealing with this very impor-
“tant question. It is of paramount importance in this
“Province also, where the fishing industry is one of the
“three most important industries in the Province. We
“would like to take some steps towards giving some
“adequate instruction to the men engaged in this
“industry.—(Signed) F. H. Sexton, Director.”

We have again to thank the United States Fisheries Department; the Smithsonian Institution; Professor E. Ehrenbaum, of the Biological Station at Heligoland; Dr. Annandale, Superintendent of the Indian Museum; Mr. E. W. L. Holt, the Scientific Adviser to the Irish Fisheries Department; and others, for further additions to our Library.

REPORT ON MEASUREMENTS OF PLAICE MADE
DURING THE YEAR 1911.

BY JAS. JOHNSTONE.

The measurements of plaice caught in the course of the routine trawling experiments, carried out by Captain Wignall and the Fishery Officers, have been made in the usual manner. They are recorded in the following series of tables, and I do not propose to discuss them here. For the most part the localities sampled are the same as in previous years; and the statistics form a useful continuation of those already published. Captain Wignall has, as in former years, devoted attention chiefly to the summer plaice fishery near Nelson Buoy, off the Estuary of the Ribble, and the winter fishery near Great Orme's Head, and in the adjacent bays, and his series of figures for the last three years is sure to be useful. Mr. G. Eccles gives a very complete series of measurements of plaice caught near the Estuary of the Mersey, particularly for a remarkable fishery which occurred in 1911 near West Hoyle Bank, opposite the Estuary of the Dee. This is just the sort of work that is admirable: whenever such an exceptional abundance of fish of any kind is observed it is most desirable that the officers should make frequent hauls and obtain good series of measurements.

Samples of plaice, sent by Captain Wignall and the Fishery Officers, have also been examined as in former years. Statistics of length, sex and age are given for various fishing grounds. It is proposed to discuss these when a sufficient mass of data has been obtained, and it has become possible to deduce the general conditions applicable to the principal fishing grounds, without necessarily taking into account the variations from year to year. Average weights for the various samples,

and for each centimetre group have also been found, but the tables are not published, since they can be summarised in a future report. In this connection I add a short note relative to the length-weight function in the plaice.

The Length and Weight Relation in Plaice.

In 1903* Professor A. Meek showed that the weight in ounces of a plaice is given by the relation $w = al^3$, l being the length in inches and a a coefficient, which was found in the series of figures considered to be about 0.0067. Subsequently Professor D'Arcy Thompson suggested that the formula

$$\text{weight in grams} = k \times \frac{(\text{length in centimetres})^3}{100}$$

should be used in fishery investigations. It was adopted by Henking and Heincke in 1907,† and has since been generally employed.

The coefficient k ranges in value from about 0.7 to about 1.2 according to the fishing ground, the season, and the length of the fish. It is a reliable index of the vague attribute known as the "condition" of the fish. When a plaice is plump and well nourished, and full of roe, k is big; when it is thin, "watery," or spent, k is small.

Generally speaking it is greatest in the early summer months, and least in the late winter, since at the latter season plaice usually cease to feed. In the case of a summer fishery, such as that carried on during the months, June to August, near Nelson Buoy and its vicinity, this is the way in which k varies; but in the case of a winter fishery, such as that carried on off the coast of North Wales during the months of October to

*Northumberland Sea-Fish. Committee. Rept. on Sci. Invests. for 1903. Newcastle, 1903, p. 40.

† "Schollen u. Schollenfischerei," Beteilig. Deutschlands a.d. Int. Meeresforsch., IV, V, Berlin 1907,

January, k attains its maximum value later in the year. These remarks apply to immature fish and males. In the case of mature females the development of the ovary and the subsequent spawning produce variations which have nothing to do with the question of the seasonal changes of "condition."

This coefficient k is the only convenient index of condition. It is true that the average weight would be just as useful, but we should then have to compare fish of the same lengths. The coefficient can, however, be found for an entire catch of fish, so that samples which differ with respect to their range of lengths can easily be contrasted.

To find k we use the formula $g = k \frac{l^3}{100}$, putting it in the form

$$k = \frac{100 \ g}{\sum (f l^3)}$$

g being the weight of all the fish in the catch, l the mean length of each centimetre group, and f the frequency at each mean length. The arithmetic involved is laborious when, as is generally necessary, the fish are arranged in centimetre groups; for the cube of each mean length has to be found* and multiplied by the number of specimens in the group, and the values found have then to be summed.

But in the investigation of a catch of plaice, average weights for each group are usually calculated in any case. In the International Fishery Investigations the lengths recorded are always means, thus all fish between, say, n and $n + 1$ cms. are recorded as $n.5$ cms. The graph of average weights is therefore a "histograph"—a series of columns of base 1 cm. in length, and the numbers are areas—the sum of the

average weights is the area of the figure between the graph and the x -axis.

If we call $f(l)$ the length-weight function, $\int_{L_1}^{L_2} f(l) dl$ is equal, therefore, to the sum of the average weights. Now assume that $f(l)$ is kl^3 and integrate this expression for the range L_1 to L_2 . The coefficient k is then easily calculated for

$$k = \frac{4 \text{ (sum of average weights)}}{(L_2)^4 - (L_1)^4}$$

Obviously it is necessary to add 0.5 to the highest mean length to find L_2 , and to subtract 0.5 from the lowest mean length to find L_1 , the upper and lower limits respectively.

Now, if such a series of average weights is found and "smoothed," a curve can be drawn very approximately through the points. If from the same series the equation $g = k \frac{l^3}{100}$ be calculated it will generally be found that its graph does not agree as closely as it ought with the curve obtained by smoothing the observed average weights.

This suggests that the length-weight function referred to above is not the best one. To find a better one we employ the systematic "method of moments" used in biometric work, and assume that the series of average weights is represented by the parabola $g = a + bl + cl^2 + dl^3 + \dots$. Generally it is necessary to find the constant a and the coefficients, b , c , d , and to do this successive "moments of inertia" must be calculated from the rough statistics, and equated to moments calculated from the theoretical equation. The simultaneous equations so formed are solved to find the constants. The method is clearly described, with examples, in Palin Elderton's "Frequency Curves and Correlation," and need not be further referred to here.

It is not laborious. It is true that the curve so calculated may not differ greatly from that obtained by the Meek-D'Arcy Thompson formula, but in some cases it does differ sufficiently to render the latter formula unsuitable for exact calculations. If, for instance, we attempted to calculate the numbers of plaice above and below a certain length (say the mean length at sexual maturity) contained in a series of catches from a specified fishing ground and season, from the commercial statistics, we should have to find the length-frequency equation, and the length-weight equation. I don't think there is any other way in which this could be done. The "*k* formula" would in this case be unsatisfactory.

Generally speaking, I have found that a series of average weights of plaice, from a definite ground and season, can be represented by the equation

$$g = a + bl + cl^2$$

if the series is a small one, i.e., the range of sizes varying, for instance, from 14 cms. to 24 cms. With a greater range another term may be necessary. But the coefficient of l^3 is always small and tends to vanish. It may be negative, and in such a case extrapolation from the curve is obviously unsafe.

But such an equation as is thus obtained would not be nearly so useful as a means of comparison of the condition of the fish, for all the coefficients would have to be considered. Obviously the simpler formula is to be preferred for such a purpose.

$$g = 83.21 + 12.20 l + 0.636 l^2 ; \text{ or } g = 0.97 \frac{l^3}{100}$$

$$g = 74.32 + 10.37 l + 0.109 l^2 ; \text{ or } g = 0.96 \frac{l^3}{100}$$

$$g = 90.77 + 14.20 l + 0.696 l^2 ; \text{ or } g = 1.22 \frac{l^3}{100}$$

$$g = 94.33 + 13.81 l + 0.697 l^2$$

$$g = 139.15 + 17.70 l + 0.649 l^2 - 0.0015 l^3$$

$$g = 147.13 + 19.20 l + 0.934 l^2 + 0.0146 l^3$$

The first term is, in all cases, the average weight of the median group.

TABLES. I.—LENGTH FREQUENCIES.

	Luce Bay, 6 inch mesh, 1911.		Off Shore from Morecambe Bay, 6 inch mesh, 1911.		
	September.		March.	April.	July.
		Mature Fish			
16.5	57	—	1	—	—
17.5	101	—	1	—	1
18.5	110	—	3	—	1
19.5	109	—	1	1	3
20.5	87	—	1	1	6
21.5	56	—	1	—	10
22.5	56	—	1	1	8
23.5	58	—	1	—	6
24.5	36	—	3	1	6
25.5	50	—	2	1	4
26.5	45	—	1	2	1
27.5	44	—	1	—	5
28.5	39	—	1	—	3
29.5	67	—	1	—	2
30.5	58	1	1	—	1
31.5	59	3	1	—	1
32.5	80	4	1	2	—
33.5	62	13	—	—	—
34.5	66	20	—	1	—
35.5	54	39	1	1	—
36.5	45	41	1	—	—
37.5	29	29	—	—	—
38.5	25	25	—	—	—
39.5	23	23	—	—	—
40.5	18	18	—	—	—
41.5	10	10	—	—	—
42.5	13	13	—	1	—
43.5	8	8	—	—	—
44.5	10	10	—	1	—
45.5	6	6	—	1	—
46.5	3	3	—	—	—
47.5	4	4	—	—	—
48.5	1	1	—	1	—
49.5	1	1	1	—	—
50.5	—	—	—	—	—
51.5	—	—	—	—	—
52.5	—	—	—	—	—
53.5	1	1	—	—	—
Totals	1491	273	25	15	58

Blackpool to Liverpool Bar, 6 inch trawl-mesh, 1911.

Nelson Buoy.							Jumbo Buoy.	Liverpool Bar.
	May.	June.	July.	Aug.	Sept.	Oct.	Oct.	Aug.
10.5	—	—	—	—	—	—	—	—
11.5	—	—	—	—	—	—	—	1
12.5	—	—	—	3	—	—	—	1
13.5	2	—	—	8	1	1	2	—
14.5	3	2	4	27	3	2	1	3
15.5	9	3	12	63	7	10	7	13
16.5	8	12	30	104	29	60	10	45
17.5	11	29	50	86	38	76	5	65
18.5	25	55	69	104	24	95	6	85
19.5	17	47	70	94	27	58	7	75
20.5	10	30	41	98	14	46	14	54
21.5	6	16	28	140	30	50	5	50
22.5	3	18	16	142	30	43	4	37
23.5	6	7	12	139	31	49	6	37
24.5	7	4	6	104	45	68	8	26
25.5	7	2	3	75	44	57	8	25
26.5	7	4	4	41	19	48	6	31
27.5	7	2	2	22	14	25	10	22
28.5	6	1	2	22	9	13	6	32
29.5	—	1	—	14	1	11	8	28
30.5	1	2	1	14	2	4	3	15
31.5	2	—	1	8	1	4	2	9
32.5	1	—	2	9	6	2	1	9
33.5	—	—	1	2	1	1	1	12
34.5	1	—	2	5	1	—	1	1
35.5	—	—	—	3	2	—	1	4
36.5	—	—	—	3	2	2	—	1
37.5	—	—	—	1	—	—	—	1
38.5	—	—	—	—	—	—	1	1
Totals	139	235	356	1331	381	725	123	683

Off Mersey Estuary, 6 inch mesh, 1911.

HORSE CHANNEL, 6 inch mesh.

	April.	May.	June.	August.	October.
10·5	—	—	—	—	—
11·5	—	2	—	—	—
12·5	—	7	—	—	—
13·5	1	9	7	—	—
14·5	—	35	33	—	—
15·5	3	94	96	4	2
16·5	20	189	364	18	16
17·5	92	299	523	57	24
18·5	255	393	524	97	21
19·5	320	432	340	151	16
20·5	255	300	296	104	4
21·5	166	250	148	131	15
22·5	141	154	92	70	11
23·5	90	98	52	44	21
24·5	61	43	21	55	24
25·5	23	21	7	27	22
26·5	11	17	6	20	19
27·5	8	3	1	11	23
28·5	1	6	—	6	17
29·5	4	1	—	4	8
30·5	2	2	1	4	2
31·5	—	2	1	4	4
32·5	1	—	—	2	3
33·5	1	—	—	—	2
34·5	—	—	—	—	1
35·5	—	1	—	2	1
36·5	1	—	—	1	—
37·5	1	—	—	—	—
38·5	—	—	—	—	—
39·5	—	—	—	1	1
40·5	—	—	—	—	—
41·5	—	—	—	—	—
42·5	—	—	—	3	—
43·5	—	—	—	—	—
44·5	—	—	—	1	—
45·5	—	—	—	—	—
46·5	—	—	—	1	—
Totals	1457	2358	2512	818	257

Off Mersey Estuary, 6 inch mesh, 1911.

OFF WEST HOYLE BANK, 6 inch mesh.

	June.	July.	August.	September.	October.	November.
10.5	—	—	—	—	—	—
11.5	—	—	—	—	—	—
12.5	—	—	—	—	—	—
13.5	—	3	—	—	—	—
14.5	1	4	—	—	—	—
15.5	3	40	—	—	—	2
16.5	19	129	7	1	3	2
17.5	48	233	37	3	3	9
18.5	102	287	39	4	4	6
19.5	182	477	72	4	5	6
20.5	213	434	70	1	6	11
21.5	171	521	88	3	5	7
22.5	165	612	134	14	6	18
23.5	139	601	102	21	3	31
24.5	143	529	119	28	5	40
25.5	93	506	135	42	10	69
26.5	78	295	100	54	12	77
27.5	60	209	57	67	8	91
28.5	25	129	36	60	19	96
29.5	21	74	18	50	24	89
30.5	6	39	13	24	10	88
31.5	—	23	11	13	9	68
32.5	—	8	3	4	11	46
33.5	—	9	—	3	4	39
34.5	1	1	—	2	5	18
35.5	—	—	—	—	3	7
36.5	—	—	—	—	1	5
37.5	—	—	—	—	1	1
38.5	—	—	—	—	—	1
39.5	—	—	—	—	—	—
40.5	—	—	—	—	—	1
41.5	—	—	—	—	—	—
42.5	—	—	—	—	—	—
43.5	—	—	—	—	—	—
44.5	—	—	—	—	—	—
45.5	—	—	—	—	—	—
46.5	—	—	—	—	—	—
Totals	1470	5163	1041	398	157	828

Near Mersey Estuary, Shrimp Trawl, 1911.

	Jan.*	March.	April.	June.	July.	Oct.	Nov.	Dec.
4.5	255	—	29	—	15	—	32	314
5.5	980	24	242	—	27	6	450	3728
6.5	692	99	189	—	1	39	1107	8495
7.5	293	161	68	3	1	76	1475	5048
8.5	161	322	40	5	15	5	725	1707
9.5	171	280	49	3	41	—	217	320
10.5	46	176	61	2	41	1	1	49
11.5	34	271	55	1	57	1	1	48
12.5	17	202	66	1	32	—	3	21
13.5	13	188	45	2	10	—	1	9
14.5	8	149	81	—	9	1	2	2
15.5	5	163	64	—	6	1	—	1
16.5	3	106	74	1	11	—	—	1
17.5	3	69	80	—	14	—	—	—
18.5	2	77	49	—	18	—	—	1
19.5	—	45	37	—	17	—	1	—
20.5	—	31	28	—	20	—	—	—
21.5	—	7	14	—	12	—	1	—
22.5	—	6	13	—	6	—	—	—
23.5	—	—	4	—	7	—	—	5
24.5	—	1	1	—	—	—	—	4
25.5	—	2	2	—	—	—	—	—
26.5	—	—	—	—	—	—	—	—
27.5	—	—	1	—	—	—	—	—
28.5	—	—	—	—	—	—	—	1
29.5	—	—	—	—	—	—	—	1
30.5	—	—	—	—	—	—	1	—
31.5	—	—	—	—	—	—	1	1
32.5	—	—	—	—	—	—	—	—
33.5	—	—	—	—	—	—	—	—
Totals	2683	2379	1292	18	360	130	4018	19756

* Includes two hauls, 28—30/12/1910.

Off Mersey Estuary, 7 inch trawl net, 1911.

	January.	March.
10.5	—	—
11.5	—	—
12.5	—	—
13.5	—	1
14.5	—	1
15.5	1	3
16.5	3	10
17.5	13	14
18.5	23	24
19.5	26	41
20.5	26	25
21.5	27	23
22.5	10	14
23.5	16	17
24.5	17	14
25.5	13	1
26.5	9	—
27.5	8	—
28.5	3	—
29.5	1	—
30.5	—	—
31.5	1	—
32.5	—	—
33.5	1	—
Totals	198	188

Conway, Beaumaris and Red Wharf Bays, 6 inch mesh, 1911.

	January.	June.	July.	August.	Sept.	October.	Nov.	Dec.
10.5	—	—	—	—	—	—	—	—
11.5	—	—	—	—	—	—	—	—
12.5	—	—	—	2	—	1	—	—
13.5	—	1	—	3	—	3	—	—
14.5	—	—	—	3	2	14	1	—
15.5	6	5	—	6	7	71	8	5
16.5	8	9	—	37	13	182	28	17
17.5	7	19	—	24	34	280	61	21
18.5	10	10	2	28	31	253	37	18
19.5	21	6	—	29	18	206	46	20
20.5	13	5	7	19	25	129	18	23
21.5	19	4	18	13	17	101	25	19
22.5	14	6	22	8	10	96	19	16
23.5	14	6	17	10	15	68	26	24
24.5	7	5	16	9	8	47	15	15
25.5	7	6	13	9	11	44	19	32
26.5	7	6	10	6	11	39	17	29
27.5	3	4	8	5	13	42	12	18
28.5	5	3	3	7	5	46	11	33
29.5	2	—	2	2	4	31	11	16
30.5	—	—	1	4	4	18	12	26
31.5	—	—	—	1	1	24	12	18
32.5	—	2	—	1	1	17	6	19
33.5	—	—	1	—	—	13	9	14
34.5	—	—	—	1	—	11	6	13
35.5	—	—	—	—	—	3	4	8
36.5	2	—	—	—	—	7	—	6
37.5	—	1	—	—	—	2	3	1
38.5	1	1	1	—	—	—	1	2
39.5	—	—	—	—	—	—	3	2
40.5	—	—	—	—	—	—	2	1
41.5	—	—	—	—	—	—	—	3
42.5	—	—	—	—	—	—	—	1
43.5	—	—	—	—	—	—	—	—
44.5	—	—	—	—	—	—	1	—
45.5	1	—	—	—	—	—	1	—
46.5	—	—	—	—	—	1	—	—
47.5	—	—	—	—	—	—	1	—
48.5	—	—	—	—	—	—	—	—
49.5	—	—	—	—	—	—	—	—
50.5	—	—	—	—	—	1	—	—
Totals	147	99	121	227	230	1750	415	420

Cardigan Bay, 6 inch mesh, 1911.

	January.	May.	June.
14.5	—	—	1
15.5	—	2	1
16.5	—	1	1
17.5	—	4	7
18.5	1	6	6
19.5	—	5	5
20.5	—	13	9
21.5	—	14	11
22.5	2	13	6
23.5	3	19	14
24.5	2	23	19
25.5	5	29	35
26.5	5	18	35
27.5	8	23	38
28.5	5	21	37
29.5	6	35	24
30.5	6	22	11
31.5	4	15	6
32.5	4	9	2
33.5	7	6	1
34.5	4	2	—
35.5	1	2	—
36.5	3	2	—
37.5	3	—	—
38.5	5	—	—
39.5	3	3	—
40.5	1	—	—
41.5	—	—	—
42.5	2	—	—
43.5	—	—	—
44.5	1	—	—
45.5	1	—	—
46.5	—	—	—
47.5	2	—	—
48.5	—	—	—
49.5	—	—	—
50.5	—	—	—
51.5	—	—	—
52.5	—	—	—
53.5	2	—	—
Totals ...	86	287	269

Carnarvon Bay, 6 inch mesh, 1911.

	March.	April.	May.	June.	July.	August.	Sept.	October.
14.5	—	—	—	—	—	—	—	5
15.5	—	—	—	—	—	—	4	10
16.5	5	1	—	1	—	—	15	16
17.5	3	7	—	1	—	1	23	24
18.5	6	4	—	1	1	5	25	15
19.5	9	5	—	2	1	12	23	21
20.5	6	5	—	—	—	7	23	21
21.5	6	3	—	—	3	4	16	15
22.5	2	5	—	2	1	2	12	15
23.5	3	4	1	—	—	—	7	14
24.5	3	2	—	—	1	1	2	6
25.5	—	6	—	—	1	—	4	4
26.5	—	5	—	—	2	—	1	5
27.5	—	4	1	1	—	—	—	5
28.5	—	1	1	—	1	—	2	2
29.5	1	—	—	—	2	—	—	2
30.5	1	1	1	—	1	—	1	1
31.5	1	—	—	1	5	—	1	—
32.5	—	—	1	2	3	—	—	—
33.5	—	1	—	—	6	—	1	—
34.5	—	1	—	—	3	—	—	—
35.5	1	—	1	1	1	—	—	—
36.5	—	—	—	—	1	—	—	—
37.5	—	—	1	—	1	—	—	—
38.5	—	1	—	—	1	—	—	—
39.5	2	—	—	—	—	—	—	—
40.5	—	—	—	—	1	—	—	—
41.5	—	—	—	—	1	—	—	—
42.5	—	—	—	—	—	—	—	—
43.5	—	—	—	—	—	—	—	—
44.5	—	—	—	—	—	—	—	—
45.5	—	—	—	—	—	—	—	—
46.5	—	—	—	—	—	—	—	—
47.5	—	—	1	—	—	—	—	—
48.5	—	—	—	—	1	—	—	—
49.5	—	—	—	—	—	—	—	—
50.5	—	—	—	—	—	—	—	—
51.5	—	—	—	—	—	—	—	—
52.5	—	—	—	—	—	—	—	—
53.5	—	—	—	—	—	—	—	—
Totals	49	56	8	12	38	32	160	181

II.—LENGTH, SEX AND AGE.

Age Groups, Barrow Channel, 1911.

[illegible]

Age Groups, Conway, Beaumaris and Red Wharf Bays, 1911.

[illegible]

INTERNAL PARASITES AND DISEASED
CONDITIONS OF FISHES.

BY JAS. JOHNSTONE.

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1. *Coenomorphus linguatula* (van Beneden).*

I am indebted to a pupil of mine, Mr. Thomas Newby, mate of the Fleetwood steam trawler "Cygnet," for four specimens of this most interesting Cestode. They were taken from a Coalfish (*Gadus virens*) caught to the north-west of St. Kilda, in 130 fathoms of water. Mr. Newby had seen them frequently, but only in coal-fish. He noticed that the worms were of a very unusual appearance and preserved part of the liver of the host in ice until the arrival of his vessel in port. Mr. T. R. Bailey, Port Sanitary Inspector at Fleetwood, sent on the specimen to me. All four worms were alive when

* The only references to the occurrence of this Cestode which I can find are :—

1853. P. J. van Beneden, *Bull. de l'Acad. Roy. Belgique*, T. XX, Partie II, p. 260, pl. I, Bruxelles.

1854. Diesing, *Sitzungsb. K. Akad. Wissensch. Wien*. XIII, p. 591.

1889. Lönnberg, E. 'Ueber eine eigenthümliche Tetrarhynchiden-larve.' *Bihang till K. Svenska Vet.-Akad. Handlingar*. Bd. 15, afd. IV. No. 7, pp. 1-48, pls. I-III. Stockholm.

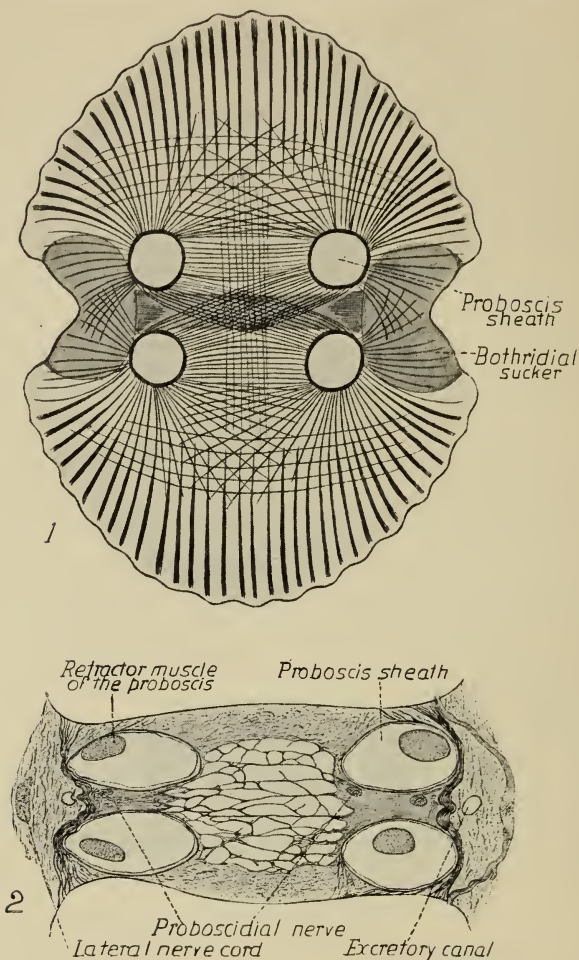
received. They were adherent by their suckers and hooks to the piece of liver, and two of them had excavated cavities in the tissue. I tried to kill one in fresh water, then in sea water containing cocaine, but without success. One specimen was preserved in Zenker's fluid and serial sections were made and stained with Mann's methyl-blue eosin. The rest were preserved in weak formalin. Fixation and staining were quite satisfactory.

The appearance of the Cestode when alive is represented in fig. 2, Pl. I, about natural size. It varied from 30 to 60 mm. in length, according to the degree of contraction, for it was very mobile. When fully extended it was quite smooth, without wrinkles or furrows, a slight constriction marked off the anterior "cephalic" part from the body, which tapered to a blunt-pointed "tail" extremity. When contracted after killing, the whole body was irregularly segmented by rather deep constrictions, and a short terminal portion—the "appendix" of Lönnberg—was retracted into a socket or sheath. In this condition the worm is figured by the latter author, who also gives an account of its morphology. I am, however, able to add some details of structure, and these may be worth recording since Lönnberg's paper is not easily accessible. At any rate, the Cestode is so rare that confirmation of the already published account may be desirable.

The Scolex. In life the scolex is quite smooth, but after fixation it is marked by a great number of longitudinal, shallow furrows (Text-fig. 1). There are two bothridia, "dorsal" and "ventral" in position, and each of these structures is an elongated suckorial organ like the sucker of a *Bothriocephalus*. Its wall consists of dense parenchymal tissue, with relatively few muscle fibres. A slight ridge runs longitudinally along

its floor, and the muscle fibres are much less prominent along the median part of the basal wall than elsewhere. These characters suggest that the bothridium really consists of two structures, the adjacent walls of which have fused together. It lies entirely below the general surface of the scolex. Its posterior wall is entire, but anteriorly the lateral walls thin out and disappear. The proboscides, four in number, are situated at the anterior extremity of the scolex. They are very short, almost globular in form, and closely covered with short recurved hooks. The dorsal and ventral pairs are in contact with each other, but a little distance separates the two pairs. Each proboscis is in relation to a sheath, into which it may presumably be invaginated, though this did not occur while I had the worms under observation. The proboscis sheaths pass into muscular bulbs. All this proboscidal apparatus resembles in every detail that of a typical Tetrarhynchid, from which the scolex of *Coenomorphus* differs only in the characters of the bothridia.

Muscles of the Scolex. These differ in some respects from those of the Tetrarhynchids. Lönnberg does not give figures of their arrangement, so I have prepared the diagram (Text-fig. 1). The muscle bundles originate either in the proboscis sheaths, or in the walls of the bothridia. The principal systems are:—(1) A very compact bundle running “dorso-ventrally” between the two bothridia, internal to the proboscis sheaths: this is represented in fig. 3, Pl. I, in transverse section, and diagrammatically in Text-fig. 1 by the darkly shaded tract joining the bothridial suckers. (2) Fibres originating in the axial parts of the proboscis sheaths. Other fibres of this series, taking origin in the dorsal sheaths, are inserted into both of the ventral sheaths, and *vice*

FIGS. 1 and 2. *Coenomorphus linguatula*.

1. Diagrammatic transverse section through the Scolex showing the arrangement of the muscles. The muscular parts of the bothridia and the dorso-ventral muscle commissure connecting them are darkly shaded. The muscle bundles radiating out towards the periphery are represented as if they were projected in a single plane: in reality they run obliquely. (See Pl. I, fig. 5, which is an actual representation of the muscle fibres seen in one section some little distance behind the transverse level taken as represented in the Text-figure). The numbers of fibres drawn are in all cases less than those actually seen in the sections.

2. The axial parts of the Scolex some distance behind the central nervous system. The coarse connective tissue between the proboscis sheaths; the proboscis nerves, and the lateral nerve cords are shown. The lateral nerve cord on the right side is seen giving off branches to the bothridial suckers.

versa, an axial decussation being formed. The dorsal sheaths themselves are not connected together by muscle fibres, nor are the ventral ones. (3) Radial fibres inserted into a peripheral fibrous zone beneath the integument. Some of these originate on the outer parts of the proboscis sheaths, while others seem to take origin in the dense parenchymal tissue in the axial part of the scolex. These bundles are represented as transverse in Text-fig. 1, but they are really oblique (see fig. 5, Pl. I). They are relatively strong and are very numerous. Not all the fibres originating on the outer parts of the proboscis sheaths belong to this series, for some of those starting from the dorsal sheaths run towards the ventral parts of the scolex, and *vice versa*, a decussation being formed on either side. Others taking origin on the dorsal and ventral parts of the sheaths run into the tissues of the bothridial suckers. (4) Transverse fibres running across from side to side of the scolex, and passing between the proboscis sheaths. (5) Fibres passing outside the sheaths in the lateral parts of the scolex; these run dorso-ventrally. There are relatively few fibres in series (4) and (5).

Series (1) and (2) are situated anteriorly to the central nervous system. Behind the latter the only muscle fibres are those connecting together the bothridia. These (Text-fig. 2) run external to the proboscis sheaths.

Longitudinal muscles. These originate as two series of fibres proceeding from the outer surfaces of the proboscis bulbs. They become gathered up into two sheets which (fig. 7, Pl. I) run backwards through the appendix, dorsal and ventral to the main lateral excretory canals. This arrangement is similar to that in other Tetrarhynchids.

The Central Nervous System. This is represented in

fig. 3, Pl. I, which is based on a reconstruction from serial sections. I am not at all sure that it is accurate in all details, for the difficulty in the investigation of the nervous system of Cestodes is that the fibrils stain only with great difficulty, or not at all. What has stained in the series of sections studied is the parenchyma, with the ganglion cells, and it is these tissues that are represented—of true nerve tracts there was no indubitable indication in the preparations. But ganglion cells were certainly present in the main cerebral mass, and some of these bodies are represented in fig. 1, Pl. I. They are typical bipolar or multipolar cells of variable size with characteristic nuclei. They are usually situated in spaces, the boundaries of which appear to be fine reticula, with some nuclei. The processes of these ganglion cells can be traced for a very short distance only, and they appear to fray out into fine fibrils. The tissue in which they are embedded is a modification of the parenchyma, with a closer meshwork, and a rather more intense staining reaction than elsewhere in the body. Part of this ground tissue appears to consist of exceedingly fine fibrils running in all directions, but whether or not this is truly nervous and not neuroglial is difficult to determine.

The central ganglionic mass lies immediately behind the strong dorso-ventral muscle bundle referred to above as joining together the bothridial suckers. It is really a commissural mass crossing the body from side to side, in the middle line, and between the dorsal and ventral proboscis sheaths (fig. 5, Pl. I). Four nerves take origin, each by several "roots," at the lateral anterior margins of this ganglionic mass, and these—the bothridial nerves, in other Tetrarhynchids, run outwards and forwards into the scolex. Two large nervous strands take

origin from the lateral and posterior margins of the ganglionic mass, and these run outwards and backwards as the lateral nerve cords. At intervals branches proceed from them into the tissues of the suckers. They are elliptical in section and can be traced backwards as far as the beginning of the appendix. Four other nerves take origin from the anterior part of the central mass and these (which are shewn in section, but not lettered, in fig. 5) run backwards in pairs between the proboscis sheaths. They become applied to the outer surfaces of the proboscis bulbs and cannot be traced further. They are the proboscicidal nerves.

Distinct regions are indicated in the central nervous mass, thus the anterior sections contain the ganglion cells, while the posterior ones display only neuroglial tissues. The number of ganglion cells is quite small, all could easily be reproduced in a plastic reconstruction of the sections. The axial part of the mass appears to be homogeneous, but the lateral parts appear to be differentiated to form tracts running outwards towards the various nerve roots. The proboscicidal nerve roots can easily be traced through the posterior sections of the mass into the ganglionic regions.

The posterior regions of the mass consist mainly of a tissue which is certainly parenchymal in nature, and a part of this is represented in fig. 4, Pl. I. I have chosen a part which contains a ganglion cell. There is, first of all, a framework of relatively coarse fibres or trabeculae, bounding (in section) roughly polygonal spaces. Filling this is the parenchyma, a tissue which in sections appears to be a reticulum, but which, no doubt, consists of homogeneous films meeting together so as to include polyhedral spaces. In the preparations we see, of course, mainly the sections of these films. Coarse

neuroglial fibres traverse this meshwork in various directions, and here and there are nuclei, belonging to the parenchymal tissue. Calcareous corpuscles, and excretory capillaries are also present, but not so much in the ganglionic region as in the more posterior parts. This parenchymal tissue is, no doubt, traversed in all directions by the hypothetical systems of nerve fibrillae which pass out into the bothridial, proboscidal and lateral nerve tracts. Of course, if it were not for the presence of the highly characteristic ganglionic cells one would have great hesitation in describing all this system of parts as nervous. The form, it is true, is that of a central nervous system and I have no doubt that such is its nature. On the whole it appears to be simpler than the corresponding series of parts in the Tetrarhynchids described.

The excretory canals. These conform in their disposition to that of a true tetrarhynchid scolex. As a rule, however, there are two main canals on each side of the body; in the specimen described there is only one. The branching and anastomoses of these canals is also similar to the condition in allied forms; a peculiar feature (noted also by Lönnberg) is the presence of very large sinuses in the posterior parts of the body: some of these are represented in fig. 7, Pl. I. Fine excretory capillaries are present everywhere in the scolex. Of "flame-cells" I have seen no trace.

The Appendix. This is represented (in section) in fig. 6, Pl. I. It is the terminal, conical extremity of the body which is capable of retraction within a terminal socket, or pouch, no doubt by the action of the longitudinal muscles. It, and the adjacent part of the body consists of a tissue rather different from that forming the rest of the animal—not parenchymal in nature, but

made up rather of very fine fibrillae running in various directions. The lateral excretory canals approach each other and finally fuse near the extremity of the appendix. Lönnberg describes a terminal vesicle, but this is represented in my sections by the common part of the main canal system and there is no real vesicle, only a cavity having a stellate figure in sections. In close proximity to the lateral canals, internal to them in the body but external in the appendix, are two peculiar plexuses of vessels. These are very narrow in calibre, have relatively thick, homogeneous walls, and anastomose with each other repeatedly. They appear to be excretory capillaries.

Nature of the Organism. *Coenomorphus linguatula* is certainly a larval form, and it may be that it corresponds to some adult Tetrarhynchid already described from some large animal, such as a porpoise or shark (since the host is itself a fairly large fish). But it differs in several respects from the typical plerocercoid larva of known species of *Tetrarhynchus*. The "cephalic segment" (bothridia and proboscidal parts) correspond, but the "post-cephalic segment" differs greatly, thus muscles and excretory canals are not present behind the scolex, except in the walls of the receptaculum scolicis, and then they form part only of the integumentary system. The appendix, too, is something quite distinct. What the organism suggests is the scolex and the unsegmented "neck" region of a Tetrarhynchid such as *T. erinaceus*.

No trace of genital organs is present. Lönnberg, it is true, describes the "anlagen" of ovaries, testes and vasa deferentia in the appendix of his specimen, but he gives no figures, and I cannot help feeling that he has mistaken the knots of excretory capillary vessels for these organs.

Fixation plays strange tricks with the appearance of these organs, and sometimes they are widely expanded, with almost invisible walls, while at other times their lumina are reduced to the merest chinks, and the walls may be quite thick.

The situation of the worm is also unusual. As a rule a Tetrarhynchid larva inhabits the body cavity, but it is enclosed in a cyst, derived partly from the larval, partly from the host's tissues. *Coenomorphus*, however, lives freely in the peritoneal cavity attached by means of its suckers and hooks in the manner of an ordinary Cestode.

What we doubtless have here is a "permanent" larval stage. *Gadus virens* is, for *Coenomorphus*, a collateral host, not a true intermediate host. I have argued elsewhere* that this is the nature of the Teleostean hosts of *Tetrarhynchus erinaceus*, which Cestode inhabits only the Rays in its adult condition, but a number of Teleosts in the plerocercoid stage. It is difficult to believe that the Ray is infected by eating such fishes as Gurnards and Whiting, in which fishes plerocercoid larvae of *T. erinaceus* are, in my experience, *always* found. The true larval host is no doubt some small invertebrate, a mollusc or crustacean, and both the Teleosts and Elasmobranchs are infected by eating these creatures. The plerocercoid and adult stages are, on this view, collateral ones, as are the hosts. The same view is also taken by Southwell with regard to the life history of *Tetrarhynchus unionifactor*, which inhabits both Teleosts and Elasmobranchs in Ceylon waters. But the Teleost in this case is, according to Southwell, a *cul-de-sac* in the life-history.

Coenomorphus is therefore probably a Tetrarhynchid

* *Parasitology*, Vol. IV, No. 4, January, 1912, p. 368.

larva which has failed to find its definitive adult host. It is present in the (modified, no doubt) oncosphere stage in some invertebrate which is eaten both by the Coalfish and by the animal in which the Cestode is sexually mature. Its situation is unusual, but so also is that of *T. erinaceus* in the body muscles of the Megrin or Halibut, and there, too, the larva is mobile, moving about like a cheese maggot in its cavity; while it is much larger than the larva of the same species which inhabits the Whiting or Gurnard. The absence of the larval cyst; the growth of a "neck" region; and the direct attachment of the scolex to the tissues of the host, are, however, features not presented by *T. erinaceus*. The reason that the sexual organs have not developed is doubtless the absence of the specific stimulus to division of the cell rudiments of these organs, afforded by the fluids of the true adult host.

Lönnberg suggests that his specimen might conceivably have been a pathological form, but apparently rejects this possibility. I have no doubt that it is not pathological, and that the only departure from normality is the capacity for an extended period of larval life, and for greater growth than occurs when the regular life history is experienced.

2. *Tetrarhynchus benedeni* (Crety).*

On July 1st, 1911, a local fisherman, working a stake-net at Roosebeck, Morecambe Bay, caught 38 specimens of the Tope (*Galeorhinus galeus*), the fishes varying in length from four feet six inches to five feet six inches. All were females with well-developed ovaries. One of these dogfishes was dissected by my

* Vaullegeard, A. "Pecherches sur les Tétrarhynques." *Mem. Soc. Linn. de Normandie*, XIX^e Vol. (ser. 2^e, Vol. 3^e) 3^e fasc. P. 265, Pl. XIII. Caen, 1899.

colleague, Mr. A. Scott, at the Marine Laboratory, Piel, and a single Cestode was found by him. I describe this worm here. It is a *Tetrarhynchus* which I have not previously seen; and its measurements are:—

Length of strobila: 85 mm.

Length of scolex: 1.92 mm.

Length of bothridia: 0.36 mm.

Breadth of bothridia: 0.42 mm.

Length of proboscis bulbs, 0.36 mm.

Length of terminal proglottis, 4.5 mm.

Breadth of terminal proglottis: 1 mm.

The worm is figured below. It is relatively long and slender, more so than any other *Tetrarhynchus* which I have seen.

Scolex. 1, fig. 3. There are two bothridia, leaf-shaped, more pointed anteriorly than at the posterior end, where there is a shallow notch, as in the bothridium of *T. erinaceus*. They project well out from the scolex, and are relatively shallow. The proboscides, four in number, arise from the antero-lateral margins of the bothridia.

The remainder of the scolex—the “head-stalk”—is rather long, and decreases at first in diameter, swelling out in the region of the proboscis bulbs, and thereafter the diameter of the neck decreases greatly. The bulbs themselves are relatively short.

These characters correspond fairly well with those of *Tetrarhynchus longicollis*, and I thought at first that this was the species represented. The armature of the proboscides is, however, quite different, the hooks and spines in each oblique row being different from each other, as in the case of *T. erinaceus*. They are very difficult to make out, but their general characters and arrangement are represented in Text-fig. 3 (2 and 3).

The two views are those seen by focussing through the same piece of a proboscis.

(a) There are two prominent and characteristic spines in each oblique row, (2), which are long and slender, and only slightly curved, and which generally lie across each other. At the base of each of these spines is a much smaller one with a wide slipper-shaped base, and a sharply bent apical portion.

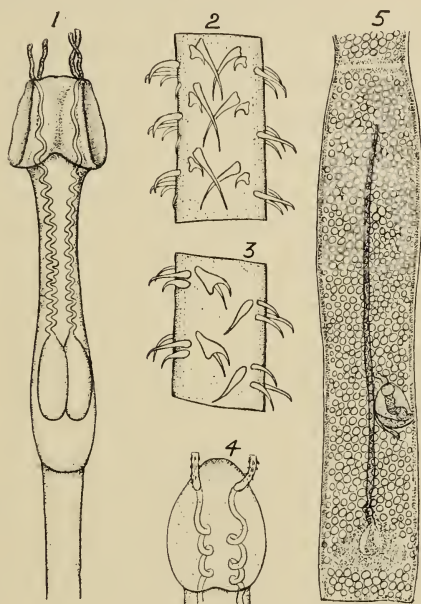


FIG. 3. *Tetrarhynchus benedeni* (Crety).

1. The Scolex and anterior part of "neck" region.
2. Part of a proboscis.
3. The same part—the obverse view.
4. A bothridium seen *en face*.
5. The terminal proglottis.

(b) Opposite to these, on the other side of the proboscis, is a group of three spines. One of these (3) is rather large, with expanded basal part, and sharply curved apex. From underneath it there projects a

longer, slender, slightly curved spine; and close to it there is another long spine, club-shaped at the base, and sharply pointed at the apex.

(c) Between these two groups of spines are other two, each group consisting of three. One of these is rather long and nearly straight, except for its sharply bent tip. The base is swollen. The other two are slender, gently curved spines.

All these groups of spines are arranged along the length of the proboscis with great regularity; and between each two of the consecutive groups (c) there is a very small, slightly curved spine which lies nearly flat on the surface of the proboscis.

These characters correspond fairly well to those of *T. benedeni* (Cretz) as described by Vaullegeard, and I identify the worm as this species.

The Proglottides.

Segmentation is very obscure for some considerable distance behind the scolex. In the single specimen obtained none of the proglottides is mature. The terminal one is represented in Text-fig. 3 (5) and it will be seen that it has the characteristic structure of a *Tetrarhynchus* segment, resembling those of *T. erinaceus* very closely except that it is relatively longer and narrower. It is in the functional male phase, and the uterus is represented only by a long narrow tube lying in the axial part of the proglottis. The testicular follicles are very numerous, and are rather small. The genital apertures are lateral and may be situated on either side of the segment, there being no definite order in their alternation.

3. *Gyrocotyle urna*, Grube and Wagener.

Two specimens of this interesting Cestodarian were found in the large intestine of a *Chimera monstrosa*,

caught off the south-west coast of Ireland and landed at Fleetwood by a steam trawler. The worm has been recently well figured by T. Scott,* and I have nothing to add to his notes regarding its appearance and occurrence.

4. *Gyrodactylus elegans*, Nordmann.

A number of specimens of a Trematode, certainly a *Gyrodactylus*, and very probably the above species, were observed on the fins of a small plaice, about 7 cms. in length, living in the aquarium tanks at the Marine Laboratory at Piel. The fish was one of a lot that had been trawled in Ulverston Channel, Morecambe Bay, but though most of those retained in the tank were examined, the Trematode was only seen on one specimen. Both dorsal and ventral fins were infected, but not the tail fin, nor the gills, and no parasites were observed on the general surface of the body. The fish could not be



FIG. 4. *Gyrodactylus elegans*. $\times 125$ dia.

examined at once, and therefore the fins were cut off and preserved in weak formalin. The state of the parasites was far from satisfactory when they were afterwards examined, and I have some doubt in identifying it as *G. elegans*, though it seems to be very near this species. The average length and breadth are about 0.4 and 0.05 mm. respectively. The large sucker bears two long recurved hooks, which are about 0.05 mm. in length; and there are six or seven pairs of smaller hooks on the margins, lateral and posterior. Most of the specimens contained embryos.

* *Twenty-eighth Annual Rept. Fishy. Bd. for Scotland*, pt. III, pl. VIII, 1891.

5. **Melanotic Sarcomata in the Skate** (*Raia batis*).

Two specimens of Skate containing such growths were received during 1911. One was part of the "wing," or pectoral fin, of a very large fish caught off the Blaskets (County Kerry, Ireland) in 130 fathoms of depth. The tumour was a very small one and was not sectioned. The other specimen was also the wing of a Skate, caught by a Fleetwood steam trawler when fishing off Dubh Artach Light (west coast of Scotland) in about 32 fathoms depth. This specimen was received in a fresh condition, and portions of the affected tissue were fixed in Zenker's fluid, in vom Rath's fixative, and in Bouin's fixative. Sections were stained in iron haematoxylin, methyl-blue-eosin, and by other methods. The fixation in vom Rath's fluid was the most satisfactory. In some cases the tissues were decolorised by prolonged soaking in hydrogen peroxide. The melanin is rendered colourless by this reagent, but the sections are very easily detached from the slide during subsequent manipulation.

This latter tumour was a large, rather irregular growth in the middle of the dorsal surface of the left pectoral fin. It measured about 10 by 6 cms. and was raised up above the general surface of the skin about 1 cm. Its surface was flat, but rather rubbed and injured, and there was also some degree of general softening, due to autolysis in the central parts of the tumour. It was very soft everywhere, and was extremely difficult to cut in the fresh condition. It was dense black in colour, and the pigmentation extended for some distance on to the adjacent parts of the integument. There were several smaller growths on the rest of the "wing," and some of these were true metastases, being distinctly raised up. Others were apparently only pigment patches. One of the more obvious metastatic

growths was cut out and sectioned. As a rule, these secondary tumours and pigment spots measured about 1 cm. in diameter.

There was no obvious indication of emaciation in the parts of the fish seen by me or Mr. Bailey, who sent the specimen.

One of the metastases sectioned, fig. 4, Pl. II, shows clearly the *locus* of the growth. The epidermis has gone from over the entire surface of the tumour and is seen only at the edge, on the adjacent skin. Three or four distinct layers of coarse connective tissue fibres are seen in the section, and the cells of the neoplasm appear to take origin in the finer areolar tissue between the more superficial layer of these coarse fibres and the epidermis, and in the deeper layers of loose connective tissue. The darkly shaded region in the figure represents the distribution of the sarcoma, and it is indicated by the figure that it is initiated between the coarse connective tissue bundles. These latter fibres themselves do not grow or proliferate in any way, but they become broken down by the growth between them of the cells of the sarcoma, and probably suffer from lack of nutrition. The lower layers of the dermis, the deeper areolar tissue, and the structures included in it, nerves, blood vessels, sensory canals and lymph vessels are not involved and are normal in structure.

The same general distribution is seen in the sections of the fully developed tumour, though the relations are less easy to make out than in the metastasis. Furthest away from the growing edge it is only the areolar tissue directly underneath the epidermis that is involved: here one sees the intrusive sarcomatous cells loaded with melanin granules. Nearer to the centre of the tumour all the fine tissue between the coarse fibres becomes

infiltrated, the fibres themselves being separated. Finally the deeper dermal structures become involved, and in the centre of the tumour the whole integument has broken down, but even there the underlying systemic muscle bundles remain unaffected.

Fig. 1, Pl. II, represents a typical part of the fully developed tumour as seen under a high power lens. It has been drawn from a section made from a part of the tumour fixed in vom Rath's fluid. The section was treated with hydrogen peroxide, but the melanin was not entirely removed. The stain was iron haematoxylin, followed by eosin. The sarcomatous cells are of various types. Many of them are spindle-shaped and two of these are represented in fig. 2, Pl. II, isolated from their surroundings. In some of these cells the nucleus is situated at one end, giving the cell a club-like appearance, but usually it lies at about the middle of the spindle. In these cells the nucleus is often quite normal in appearance, though perhaps the chromatic skein, or synapse, is more pronounced than in undifferentiated cells, and the linin substance is colloid-like. As a rule, however, the nucleus is not easily seen in these cells and is, no doubt, the seat of melanin deposition and degenerative changes.

Many other cells are short spindles, or are "oat-shaped," but the greater number are round, irregular, and variable in size. Some of these are represented in the figure; like the larger spindle cells, they possess nuclei which vary very greatly in appearance, owing to the amount of melanin deposited. No traces of nuclei are to be seen in some of them, and the cell looks like a locus only for the aggregation of melanin granules.

These cells, varying in shape and size from elongated spindles about 0.08 mm. in diameter to round cells only

about one-tenth of this in length, with a very fine connective tissue stroma, disintegrated cell fragments, and apparently loose melanin granules make up the general mass of the tumour.

In some parts of the tumour, and after successful staining with methyl-blue-eosin, there are generally distributed masses of "eosinophilous" cells, or numbers of such cells lying singly among the surrounding melanotic and connective tissue elements. Some of these are represented in fig. 3, Pl. II. They stain bright red, and stand out clearly from the other cells containing melanin. As a rule, their nuclei are not very easily seen—the defect of the staining method, for treatment with haematoxylin and eosin shows the nuclei clearly, though the general distribution of the cells themselves is not then so obvious. It is noticeable that many of these brightly staining cells appear to be situated in cavities, and to lie loosely with no obvious relation to the stroma. For the most part they are either modified or unmodified red blood corpuscles, and their general distribution is due to the breakdown of the walls of the capillaries and smaller arteries and veins. Fig. 3 thus represents what is apparently a large capillary, or small vessel, with an incomplete wall. Sarcomatous cells, containing melanin, surround this wall, and it would even appear that some of these cells adhere to it. Not all the eosinophilous cells, however, are blood corpuscles, some of them appear to be leucocytic in nature, and some have deposits of melanin. This infiltration of the sarcomatous tissue by migrant cells, or blood corpuscles, can be traced in most parts of the tumour; in fig. 1, for instance, a red blood corpuscle is shown.

The growth is, therefore, a melanotic, mixed-cell sarcoma, showing a general tendency on the part of the

cells to assume a spindle shape. I have now seen four examples of this condition, and Dr. G. H. Drew records what is apparently the same thing. In all my specimens the neoplasm is to all appearance what would be described as a malignant sarcoma. In all it is chiefly the upper layers of the dermis, more precisely the fine areolar tissue, which is involved, and which has taken on the characters of malignancy.

6. Melanotic Sarcoma in Ray (*Raia clavata*).

A large Ray, sent by Mr. T. R. Bailey, exhibited a growth of this nature. The fish was about two feet in breadth, and was landed at Fleetwood by a steam trawler. It was in very poor condition. There was a large tumour on the dorsal surface of the head at about the level of the eye. The growth was nearly globular in shape, measuring about 70 mm. in diameter. It was raised up above the general level of the skin about 40 mm. At its origin in the skin of the head its diameter was about 55 mm. It was dense black in colour except in one small area on the posterior surface. It was extremely soft, damaged in one place, and almost semi-fluid below this place of injury. Necrotic change had evidently taken place. Where uninjured the tumour was covered by the remains of the integument, and a few small spines were present. There were a number of black patches on both dorsal and ventral surfaces of the body. Some of these were distinct metastases, presenting raised surfaces, but most of them were pigment patches: they varied from one to two cms. in diameter. The skin immediately round the tumour was also pigmented.

A smaller tumour was attached to the posterior border of the eye, projecting over the spiracle, the opening of which was about half-covered by it. It was

attached by a narrow base to the integument covering the eye, and no other part of the latter organ was involved. It was yellow-white in colour, and very hard and compact.

The tumour on the head was very similar in appearance to the melanotic spindle-celled sarcoma described by me in last year's Report*, but it was larger and softer, and the metastases in the fish now described were not present in the former specimen. In both cases there was emaciation of the fish. In the tumour now being described, diagnosis is more difficult than in the Port Erin specimen, for necrosis, and secondary changes, have made the tissue far less characteristic in appearance; and owing to the overgrowth of the tumour itself on the surrounding skin it is far less easy to trace the transitional integumentary tissues. The neoplasm, however, involves the connective tissues of the skin, mainly the layer between the epidermis and the strong and coarse fibrous bundles that lie underneath: this, and to a less extent, the other connective tissue layers deeper down, are the regions of active proliferation.

Fig. 5, Pl. II, represents a part of a section not far from the growing region of the tumour. The fish had necessarily been preserved in formalin so that the fixation was not good. The sections were stained in various ways, on the whole methyl-blue-eosin, or Ehrlich's haematoxylin, followed by eosin, gave the best results. In the older parts of the tumour the tissue elements are greatly broken down, so that it is very difficult to identify them. The whole tumour is deeply impregnated with melanin granules, and these further obscure its structure, even when much of the pigment has been removed by a

* Rept. Lancashire [Sea-Fish. Laby. Liverpool, for 1910; in *Trans. Liverpool Biol. Soc.*, Vol. 25, 1911.

prolonged bath in hydrogen peroxide. Blood vessels are fairly abundant, but their contents are generally difficult to identify, and in many places the red corpuscles have broken down.

The basis of the neoplasm is a rather loose connective tissue stroma, generally enclosing irregular, elongated spaces. Apparently isolated nuclei lie among this tissue: these evidently belong to the fibres. Within the spaces of the stroma are cells which, on the whole, are short spindles in shape. Many of them are loaded with melanin granules, and in these cases the nuclear structure is obscure: probably the chromatic skein has quite broken down. In other cells, however, the nucleus has the usual structure. Cell fragments, and even apparently loose aggregations of melanin are also present, and the figure shows a piece of one of the coarse connective tissue fibres belonging to the layer which lies nearest to the epidermis.

The tumour on the eye is evidently a hard fibroma. Part of it is represented in section in fig. 8, Pl. II, and it will be seen that we have to deal with a tissue composed almost entirely of relatively coarse fibrous bundles running in all directions. The growth presents no very remarkable characters.

7. Fibro-Sarcoma from *Gadus callarias*.

A growth cut from the snout of a cod, and sent to me by Mr. Bailey, appears to be of the nature of a fibro-sarcoma. It was about 7.5 cms. long, 4 cms. in width, and was raised above the general surface of the head of the fish about 3 cms. The outline figure below (Text-fig. 5) represents its general appearance. It was greyish black in colour; and it was not capsulated in any degree, its tissue passing continuously into that of the head. It showed two small areas of softening. It was received

preserved in formalin, and sections were made and stained by Mallory's connective tissue method, after previous mordanting in Müller's fluid.

The tissue of the tumour was compact and hard, and had all the appearance of a fibroma. But on examining the sections it was seen that it was not a typical fibromatous growth but possessed certain marks of malignancy. Fig. 6, Pl. III, represents a part of the

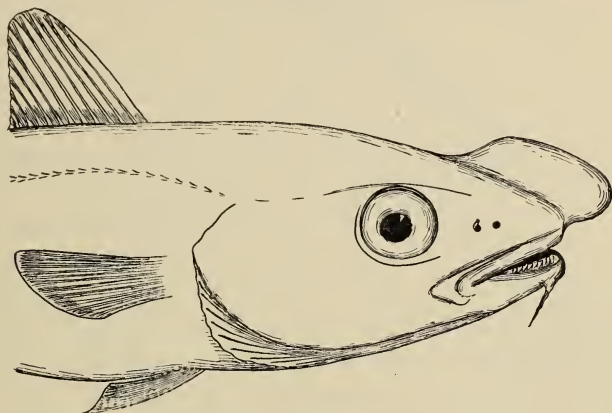


FIG. 5. Cod with Fibro-sarcoma on snout.

tumour where the fibrous elements were mixed with small round cells. Not all the tumour was so richly cellular as this part, and in the denser parts relatively few cells were present. In other places the cellular elements were, however, much more abundant than in the part represented by fig. 6. In fig. 7, for instance, part of the tumour, consisting almost entirely of irregularly shaped, somewhat stellate cells, is shown; and this may pass into such a tissue as is represented in fig. 8, small round cells, some showing a distinct tendency to become spindle-shaped.

Such round-celled tissue, containing relatively little fibrous elements, forms conspicuous nodules in the

tumour; and here and there are places where the fibres themselves are seen to be undergoing a kind of colloidal degeneration.

Over all the surface of the tumour the epidermis is absent, and the superficial layers consist of coarse connective tissue fibres.

8. **Lympho-sarcoma producing Exophthalmos in a Flounder** (*Pleuronectes flesus*).

The fish displaying this peculiar condition was sent to me by Mr. T. R. Bailey. It had been caught in Morecambe Bay, during August, 1911. It was a spent female, 31 cms. in length, and in indifferent condition with regard to nutrition. The pigmentation on the body was normal, but the dorsal, ventral and tail fins were almost white. The left eye was situated on the summit of a protuberance about 21 mm. in height, and about 20 mm. in diameter at its base. Near the upper margin this protuberance was very slightly constricted. It was elliptical in section, measuring about 20 and 16 mm. in its principal diameters. Seen from the ocular side of the body, there was no trace of an eye, but on looking at the protuberance from the blind side, the pupil could just be distinguished. The cornea was nearly opaque, and through it the lens could just be seen. On cutting through the cornea it was seen that anterior and posterior chambers had fused: the iris was quite broken down; and the lens was lying loose among a mass of leucocytes and blood corpuscles. The head of the fish is shewn, two-thirds of its natural size, in fig. 6. The other (right) eye was quite normal, and apart from the exophthalmos, and the peculiar absence of colour on the median fins, the fish was normal.

Text-fig. 7 represents a dissection of the fish from

the blind side. The anterior part of the dorsal fin, with its underlying body muscles and skeleton, has been cut away, and the roof and left part of the cranium have also been removed. The tumour is now seen to be more

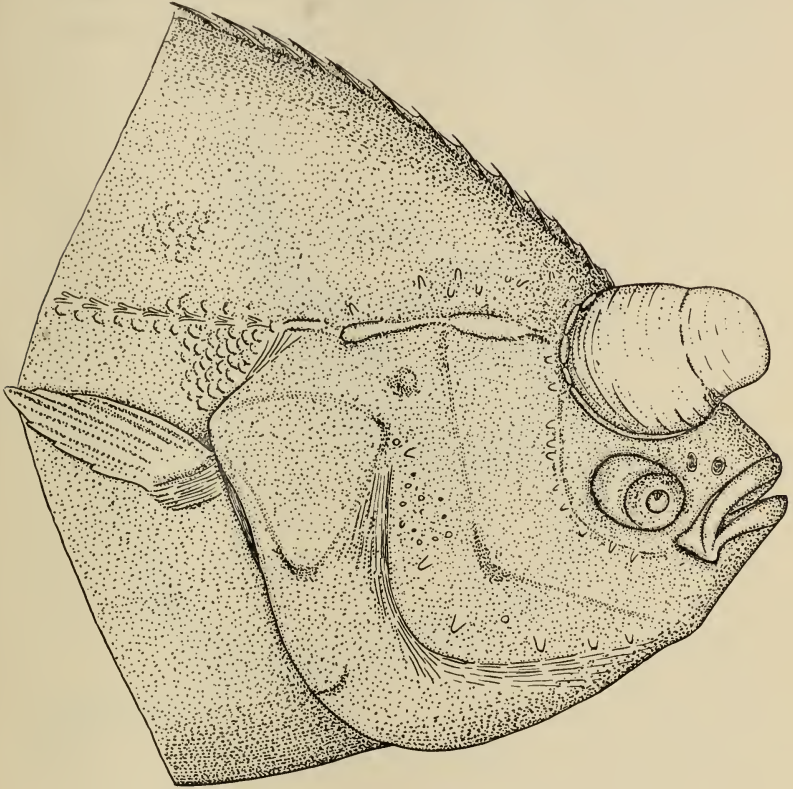
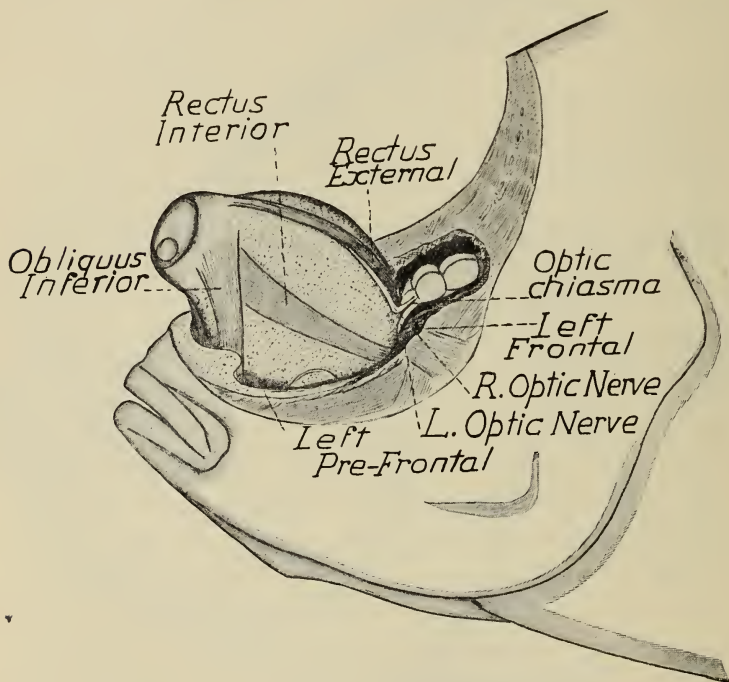


FIG. 6. Flounder with Lympho-sarcoma. Nat. size.

extensive than its external appearance indicates. It fills up the entire left orbit, forcing the eye out of its place. All the eye muscles are present and are in nearly their normal relations to the bulbus oculi. The inferior and superior obliqui are not much different in position and length from the same muscles in a normal fish: their

positions have, of course, led to the development of the tumour in the part of the orbit behind them. The internal and external recti are shown in the figure: they are longer than in the normal condition, are attenuated, and flattened out into sheet-like structures. The superior and inferior recti are not represented in the figure, being



hidden by the mass of the tumour. All the eye muscles lie on the surface of the tumour, and do not pass into its substance at any place.

The optic chiasma is normal, and the right optic nerve bends sharply upwards as it leaves the brain cavity, and runs along the posterior surface of the tumour. It really lies directly underneath the rectus externus, but

the latter has been pulled a little to one side in making the dissection for the figure. The nerve itself is partly atrophied. It is greatly flattened out, and near the bulbus it consists of relatively few fibres. It cannot be traced into the bulbus, and it is evidently undergoing degeneration, although the imperfect fixation of the specimen did not allow of this condition being minutely studied.

Underneath the tumour, and between the latter and the floor of the orbit, was a small flattened body, fatty and semi-transparent in appearance, with a little black pigment. This is indicated in fig. 7. It is apparently the remains of the recessus orbitalis.

Nature of the Tumour.

The fish had been preserved in weak formalin before being sent to me, and the fixation of the tumour was far from being all that could be desired. Nevertheless, almost all details of its minute structure could be determined, and I think there is little doubt as to its nature. It was surrounded by a very loose investment of fibrous tissue, and under a low power a complete transverse section showed what appeared to be a number of bundles of connective tissue radiating out from one main point on the margin of the growth, with two other series of bundles radiating out from adjacent parts of the margin. Outside the tumour were the sections of the muscle bundles, and that of the optic nerve.

The greater part of the substance of the tumour is made up of loose, delicate, fibrous, connective or elastic tissue bundles, running mainly parallel to each other, and forming what might be called the trabeculae or framework of a stroma, consisting of a very delicate reticulum. But towards the external part of the tumour these fibres

are peculiarly modified: they become greatly enlarged, or thickened, as if they were undergoing some kind of colloidal degeneration. Fig. 6 of Plate II represents such a thickening of the fibres, and their adhesion together in bundles. These thickened fibres are at first quite structureless, and they stain bright red with Mann's methyl-blue-eosin, and orange with Mallory's connective tissue stain. The large fibre in fig. 7, Pl. II, shows the further progress of this degenerative change. The fibres now display what appears to be a very delicate, faintly-staining reticulum (blue with both of the stains mentioned), the interspaces of which contain a substance which does not stain at all. Between these thickened fibres is the general stroma of the tumour: this is represented in fig. 7: it resembles nothing so much as the reticulum of a lymph gland. This reticulum is continuous with the enlarged fibres mentioned above.

All this reticulum contains great numbers of very small cells occupying its interspaces, and two kinds of cells are present: (1) small cells, the nuclei of which measure about 0.002μ in diameter. The cell bodies of these hardly stain at all with either Mallory's stain, methyl-blue-eosin, haematoxylin and eosin, iron haematoxylin or Romanowsky's stain. When the latter reagent is applied to a smear made from the tumour, the cell bodies belonging to these nuclei can just be seen. (2) Larger cells, staining red with Mallory's combination, and measuring about 0.005 mm. Some of these cells are represented in fig. 1, Pl. III. In the parts of the tumour where the connective tissue fibres are undergoing the modification mentioned above, some of these cells can be seen (fig. 6, Pl. II) between the adhering bundles of fibres, or even included in the structure formed by the fusion of the latter.

Large spaces exist in all parts of the tumour, and some of these are true lymphatic vessels. Usually they contain the larger cells belonging to category (2), but often they appear to be empty. Blood vessels are very few and are difficult to identify. Some of the smaller lymph vessels contain relatively large bodies, apparently formed by the fusion of the cells mentioned, or by the accumulation of some substance within them: the largest of these bodies measures about 0.05 and 0.01 mm. along its main diameters. They are loaded with brown or black pigment granules. Some are represented lying freely in a lymph vessel in fig. 1, Pl. III.

Sometimes a small vessel, lymphatic or blood-vascular, it is difficult to say which, contains numbers of the cells (2) adhering to its walls. This suggests an inflammatory process.

In a section parallel to the main diameter of the tumour, it is seen that the interior of the bulbus oculi also contains the same kind of tissue that is found in the tumour outside. The sclerotic is incomplete in the section, so that a large cavity, much bigger than that necessary for the passage of the optic nerve, must be present. There is no trace of the choroid layer, and only the merest indication of the pigmented layer of the retina. Through this cavity the foreign tissue is continuous. I think there is little doubt that the growth is a lympho-sarcoma. It resembles strongly a small round-celled sarcoma, but the connective tissue stroma is so strongly developed, and the general suggestion of the structure of a lymphatic gland is so striking that one feels obliged to call it a lympho-sarcoma. The original site of the growth was probably the choroid layer of the retina. Identification of the growth as a glioma was suggested by the destruction of the retina, but no traces

of glial elements could be made out in the tissues of the tumour. There were no traces of similar growths in other parts of the body, in the pseudobranch, for instance, or in any part of the gill-system, so it does not appear likely that the neoplastic cells were conveyed to the eye in the blood stream from other parts of the body. Of course, the peculiar vascular arrangements of the eye—the ophthalmic artery originating in the pseudobranch, and the choroid gland, suggested such an origin for the tumour, but it is probable, I think, that the growth is a primary one.

9. Ectasia of the Sensory Canals of *Raia clavata* with intra-cystic Myxofibromata.

The head portion of a large Ray, sent to me by Mr. Bailey, presented a most peculiar appearance on account of the presence of large vesicles both on the dorsal and ventral surfaces. On feeling these vesicles with the finger it was apparent that they contained some solid growths, but here and there they were soft, the walls were thin and transparent and they contained only liquid. Noticing the form of the vesicles more closely, it was seen that they were symmetrically disposed on both sides of the middle line of the head, and a curved line drawn along their median parts corresponded very closely to the direction of the sensory canals in a normal fish. The vesicles are, in fact, the cephalic sensory canal system dilated throughout its entire course, but with constrictions here and there which confer on it the peculiar vesiculated appearance.

Plate IV is the reproduction of a photograph of the ventral surface of the head, and shows, on the right (of the photograph), the untouched condition of the canals, and on the left, the cavities cut open. If this is com-

pared with a good figure of the sensory canals of the Skate, Ewart and Mitchell's for example*, it will be seen that there is no doubt as to this interpretation. All the canals figured in fig. 7, Pl. III. of the memoir cited are present, though some are not clearly shown in the photograph. That part of the infra-orbital canal lettered *I.O.4* to *I.O.5* by Ewart and Mitchell; the part of the hyomandibular lettered *H.M.*; the sub-orbital *S.O.4* to *S.O.5*; and the infra-orbital *I.O.6* to *I.O.7* are greatly dilated, and some of these dilatations present themselves as vesicles about 3·5 cms. in diameter, and raised up above the general level of the skin by as much as 1·5 cm. Some of the canals are not much greater in calibre than in the normal fish: these are the infra-orbital *I.O.7* to *I.O.8*; the supra-orbital *S.O.3* to *S.O.4*; the infra-orbital, *I.O.3* to *I.O.4*, and *I.O.6*; and the hyomandibular adjacent to its union with the infra-orbital. On a first examination it appeared that some of the canals were absent, but they were found beneath the floors of the larger vesicles. This was the case with the hyomandibular, and part of the supra-orbital. In these cases the hidden canals were of the normal calibre.

There is not nearly the same amount of dilatation of the canals on the dorsal surface of the head; but the two supra-orbitals *I.O.7* to *I.O.8* are dilated, the greatest diameter being about 1·5 cm. In front and external to the left orbit there is also a large and complex cyst, which is about 4 cms. in diameter, is raised up above the general surface of the skin about 1 cm., and is depressed below the surface about 1·5 cm. It occupies the place of junction of the hyomandibular and infra-orbital canals, and is almost certainly made up of

* *Trans. Roy. Soc. Edinburgh*, Vol. 37, 1891-2, pp. 87-105, pl. III, fig. 7.

expanded portions of these tubes. From it runs forwards a large canal, also dilated to about 0·5 cm. in diameter: this is probably Ewart and Mitchell's *H.M.4* to *H.M.5*. A smaller round cyst, about 1 cm. in diameter, projects out from the antero-median surface of this large cyst, and a large cyst, with semi-transparent walls, and about 2·5 cms. in diameter, lies on the floor. With these exceptions, the dorsal surface of the head is normal.

The cavities contain a transparent, sticky fluid, which is probably very similar to that secreted by the sensory canal epithelia. Within them are the intracystic growths, and these are very peculiar in nature. All the dilated canals contain these growths, but in some of them, the right supra-orbital on the dorsal surface, for instance, the growths are small, round, worm-like bodies, slightly yellow in colour, and translucent. They are smooth and are rarely branched or lobulated. Some of these bodies are represented in fig. 2, Pl. IV.

The other growths are white in colour, fairly hard, sometimes with a peculiar glistening appearance, and of the most extraordinary shapes. Two of the larger ones are represented in Pl. IV. The largest is about 8 cms. in length and about 1·5 cm. in diameter at its widest part. The two growths represented were attached to the internal wall of the cyst by very delicate pedicels, the remains of which can be seen in the photograph, and they were very easily detached. They were taken from the expanded part of the infra-orbital canal, and one lay in each of the large vesicles, but the larger of the two projected into the hyomandibular canal. The other dilatations on the ventral surface contained only the smaller yellow bodies. It will be seen from the photograph that the larger growths are produced into appendages, lobes, and that they are racemose or

botryoidal in form. It is difficult to describe them, but the photographs convey a very good idea of their appearance. The growths in the left supra-orbital canal on the dorsal surface are quite similar, but part of the floor of the cyst in this case is seen to be produced into hard white ridges of varying form, and these can easily be traced into the growth. Both in this canal, and in the large cyst of the dorsal surface, the growths are very firmly attached to the floor of the canal. In the large cyst some of the growths have proliferated from the roof of the cyst, and one of them has either broken through, or has evaginated, so that it is visible without cutting open the cyst. In the photograph of the ventral surface, two of the growths are seen still attached to the floor of the cyst.

Nature of the Tumours. Fig. 2, Pl. III, represents part of a section of one of the smaller, white, irregular growths, stained with Mallory's combination. The substance of the tumour is very uniform, consisting of a fine fibrous tissue containing relatively few blood-vessels. One of these blood-vessels is cut in the section: it contains three red blood corpuscles and a leucocyte. Outside the blood-vessel are a number of similar leucocytes, and the aggregation of these cells round small vessels is quite typical of the tissue. The remaining elements of the tumour are very fine connective tissue fibres, with very few nuclei. The fibres run in all directions, except round the blood-vessels, where their general course is concentric to the section of the vessel. The tumours have a very distinct epithelium, continuous with and similar to that lining the cysts. Its structure (which is not easily made out on account of the formalin fixation) is represented in fig. 3, Pl. III. The cells are columnar, the free edges being usually confluent, or

apparently so; and the nuclei are situated usually about their middles. Interpolated between them are elongated granular bodies without nuclei, and coarsely granular, and there are a few large "goblet" bodies. The epithelium rests on a coarse reticulum, the exact structure of which is difficult to make out.

Such a structure is quite consistent with the interpretation of the tumours as intra-cystic myxofibromata. They are apparently comparable in structure with polypoid growths on the naso-pharyngeal epithelium, and they are indeed present in a highly mucous cavity. It is true that the stellate nucleated cells with long processes, described as present in typical growths of this nature, could not be seen in the large white cysts, but the latter were probably too highly developed, and the typical structure need not, of course, be postulated for identification.

The production of the cysts is, it seems probable, to be accounted for by the occlusion, or the congenital absence of the sensory canal pores. These are not very numerous, and the absence of most of them would lead to the production of mucus within the canals at a greater rate than it could be removed. It was, of course, difficult to be sure that the majority of these pores were absent, but since the liquid in the large vesicles must have been there under pressure, it is obvious that pores could not have been present in normal number. There may also have been occlusion of the canals at some places by the intra-cystic growths, and it may well be the case that the formation of these, together with the congenital absence of pores, was the cause of the remarkable dilatation of the canals.

10. Cutaneous Papilloma from a Halibut (*Hippoglossus vulgaris*).

In November, 1911, Mr. F. Stokes, Port Sanitary Inspector at Grimsby, sent me a piece of tissue weighing about two pounds, cut from off the snout of a halibut landed at Grimsby. The fish was about 120 lbs. in weight, and the Inspector was of opinion that it was "well-fed" and in good condition, apart, of course, from the growth on the head. The latter, however, was a very extraordinary one. It was very irregular in shape, so that in the cut-out specimen it was almost impossible to be sure of the relations of its parts to the head of the fish. It was pigmented much in the same manner as the skin of the upper surface of the fish, but was perhaps darker in places. The free surface was everywhere thrown into fungoid, or "cauliflower-shaped" excrescences. In some places these protuberances were large, lobulated and botryoidal, presenting in fact a great variety of appearances. In other places the surface of the growth was very minutely papillated, and dead grey white in appearance. It is very difficult to describe the appearance of this growth. It was very hard and dense, presenting in its internal parts all the appearance of a hard fibroid tumour. In the deep the tissue was mainly aggregated in nodular masses, presenting a dead white, sometimes glistening, appearance. The tissue, both directly underneath the surface of the tumour and in the deeper parts, was very difficult to manipulate when cutting sections. It was extremely hard after embedding in paraffin, and could only be cut with great difficulty. Staining, too, was difficult on account of the formalin fixation, but fairly good results were obtained with Ehrlich's haema-

toxylin followed by eosin. I give, in the meantime, only a provisional account of the structure of this growth.

Fig. 5, Pl. III, represents a vertical section through the outer part of the finely papillated portion of the tumour: the little protuberances standing out above the surface are the sections of these smaller papillae. Below them the tissue consists largely of bundles of coarse connective fibres running in every direction. Two series of bundles do, however, assume prominence: (1) very coarse fibres running nearly perpendicularly to the surface of the tumour into the interior of the papillae, and branching and apparently anastomosing freely; (2) coarse fibres running approximately perpendicularly to these in the deeper parts of the tumour. These also branch, adhere together, and anastomose. In methyl-blue-eosin all these coarse fibres stain at once a very intense blue, and the same intense staining results from treatment with Mallory's combination. When treated with carbol-gentian the lower parts of the tumour (at this particular place) give a very decided mucin reaction.

Mingled with these coarse, intensely staining fibres are finer ones, and these form a general stroma which penetrates into the interiors of the papillae. Fig. 4, Pl. III, represents part of the tissues within one of these papillae, the external surface being to the left in the figure. There is no evident epithelium on the surface of the tumour, and no trace of epidermis, and one can only see a kind of limiting membrane of very obscure structure. The tissues within the papilla consist of a fine areolar network with numerous nuclei, bundles of coarser fibres, and some of the very coarse connective tissue fibres from the lower parts—none of the latter is, however, represented in the figure. The papilla is very vascular, and sections of a capillary knot are shown:

these contain blood corpuscles, but the number of the latter is relatively few.

Everywhere in sections of the papillae, and in the tissues directly underneath, are capillary tubes ramifying to an extraordinary extent, branching and anastomosing very freely. They are most numerous directly beneath the surface, where they form an irregular layer, but they are present also in the depths: they are represented in fig. 5 by the lines of dots. Some of them are shown in fig. 4, and are represented as filled with short fibrils. I thought at first that the contents of these vessels were granular, but examination under high power lenses shows the fibrillar nature of this material. In unstained sections this substance is coloured light brown in mass, but where a few of the fibrils can be seen at the cut edges of the preparation, they appear to be nearly colourless. They present a glistening appearance when seen by reflected light. They do not stain with methyl-blue-eosin, Mallory's combination, Ehrlich's haematoxylin and eosin stain, iron haematoxylin, or eosin alone. They do not Gram-stain, nor do they take stain from carbol-gentian. I thought at first that they might be bacterial in nature, or perhaps the hyphae of a fungus, but the negative staining reaction makes these interpretations impossible. They do not react in any way to dilute acetic acid, and cannot be crystals of lime. They are not lipid for they do not dissolve out under treatment with xylol. They are some kind of inclusion in the tissues of the growth, contained either in capillary blood-vessels or in channels of their own.

The deeper parts of the growth vary in minute structure. In many places what is seen is essentially the condition already described in the case of the fibro-sarcomatous tumour from the cod; that is, there is a

basis of either coarse or fine connective tissue fibres, and included in the interstices of this are numerous small round cells. Sometimes this tissue resembles that shown in fig. 7, Pl. III, but it is always much denser, and the cells are, relatively to the fibrous stroma, more numerous. It is sometimes very vascular, but the contents of the blood-vessels are peculiar. Sometimes a smaller vein or artery contains practically unmodified red blood corpuscles, but these are generally aggregated together in the centre of the lumen of the vessel. In other places the blood corpuscles appear as if they were "clumped" or agglutinated: the nuclei are few in number, or entirely absent, and the cell margins are indistinct as if the corpuscles had stuck together. Very often the space between the axial mass of corpuscles and the internal walls of the vessel is bridged by delicate fibrils, radiating out in a stellate manner, and suggesting the staining of fibrin filaments produced after intra-vascular coagulation of the blood. I am uncertain whether this coagulation has been produced in a natural manner, or as the result of the fixation; practically undiluted commercial formalin solution had been employed for preservation. But I am inclined to think that the intra-vascular coagulation is a natural reaction produced in the development of the tumour. The walls of the blood-vessels themselves are highly modified, and sometimes cannot be distinguished from the surrounding connective tissue stroma. If this alteration of the blood has taken place as the result of some toxic substance produced locally, it may be the case that the other vessels, with their fibrillar inclusions, have also been produced in this manner; that is, they may be capillary vessels containing crystalline products of the decomposition of the haemoglobin of the blood. I have already

seen extensive crystallisation of the haemoglobin in the case of a plaice which died in the tanks at Port Erin, and which had ulcerated patches on its skin.

Elsewhere the growth has the characters already described, with some modification. It is mostly fibrous, sometimes finely fibrous, but at other times the structure is very coarse and the fibres seem to be swollen and degenerate, undergoing some kind of colloidal change. Here and there are patches, or nodules of proliferation, when there are very numerous small round cells. We conclude that the growth is a cutaneous papilloma—a kind of gigantic wart; with indications of a tendency to the production of local malignancy.

EXPLANATION OF THE PLATES.

PLATE I, figs. 1-7.

COENOMORPHUS LINGUATULA (van Beneden).*

- Fig. 1. Ganglionic part of the central nervous system. Zeiss apochromatic 1.5 mm.
- Fig. 2. The animal in the extended condition. Slightly reduced.
- Fig. 3. The anterior part of the Scolex. Reconstructed from serial sections, and seen from the "dorsal" surface. Only two of the proboscides, and two proboscidial bulbs and sheaths are represented. Mag. about 10 dia.
- Fig. 4. The central nervous system. The parenchymal ground tissue is all that is represented in addition to a ganglion cell and an excretory canal. Zeiss apochromatic 1.5 mm.

* *Tetrarhynchus megacephalus*, Rud., may be the final form of *Coenomorphus*.

Fig. 5. Transverse section of the Scolex passing through the central nervous system. Mag. about 10 dia.

The figure should be compared with Text-fig. 1, p. 106, which is based upon this and the adjacent sections of the series.

Fig. 6. Transverse section near the posterior extremity of the animal, and passing through the appendix. The crescentic cavity is produced by the involution of the integument consequent on the retraction of the appendix. Mag. 20 dia.

Fig. 7. Transverse section passing through about the middle of the animal. Mag. 14 dia.

PLATE II, figs. 1-8.

Fig. 1. Melanotic sarcoma from *Raia batis*. Round and spindle cells containing melanin granules; diffuse melanin granules; slight connective tissue stroma; nuclei of cells either modified or normal.

Fig. 2. The same. Two typical spindle cells. Length about 0.08 mm.

Fig. 3. The same. Part of the tumour where a breakdown of the walls of the blood capillaries has occurred. The darkly shaded cells belong to the sarcoma; the lightly shaded ones are red blood corpuscles.

Fig. 4. The same. Section of a metastasis. The darkly shaded part represents the sarcomatous tissue; on the left, part of the epidermis. All the structures shown belong to the integument.

- Fig. 5. Melanotic sarcoma from *Raia clavata*. Cells of rather irregular shape showing a tendency to spindle formations. Marked connective tissue stroma. The darkly shaded object is part of a connective tissue fibre.
- Fig. 6. Lympho-sarcoma from the eye of *Pleuronectes flesus*. Fibrous part of the growth, showing colloidal swelling and fusions.
- Fig. 7. The same; an enlarged connective tissue fibre showing a reticular structure. Fine meshed reticulum enclosing leucocytes.
- Fig. 8. Fibroma growing on the integument of the eye of *Raia clavata*. Coarse fibrous tissue with few cells.

PLATE III, figs. 1-8.

MORBID HISTOLOGY OF FISHES.

- Fig. 1. Lympho-sarcoma from the eye of *Pleuronectes flesus*. Lymph space containing leucocytes, some of which contain melanin. A smaller lymph space on the right containing leucocytes most of which are adherent to the walls.
- Fig. 2. Myxo-fibroma from *Raia clavata*. Fine fibrous tissue running in all directions. A blood-vessel containing several blood corpuscles and a leucocyte. Numerous leucocytes in the tissue surrounding the vessel.
- Fig. 3. The epithelium covering the myxo-fibromata sectioned in fig. 2. Columnar cells, with interpolated mucus cells, resting on a coarse connective tissue stroma, containing cells in its interstices.

- Fig. 4. Cutaneous papilloma from the Halibut. Part of one of the papillae represented in section in fig. 5. Richly vascular connective tissue: a capillary knot is cut through. Vessels containing finely fibrillar inclusions.
- Fig. 5. Cutaneous papilloma from the Halibut. Section of the external part of the growth.
- Fig. 6. Fibro-sarcoma from the Cod. The more fibrous part of the tumour, but containing also numerous small round cells.
- Fig. 7. The same. Irregular stellate cells.
- Fig. 8. The same. Small round cells, some showing spindle forming tendency. Relatively little fibrous tissue.

PLATE IV, figs. 1 and 2.

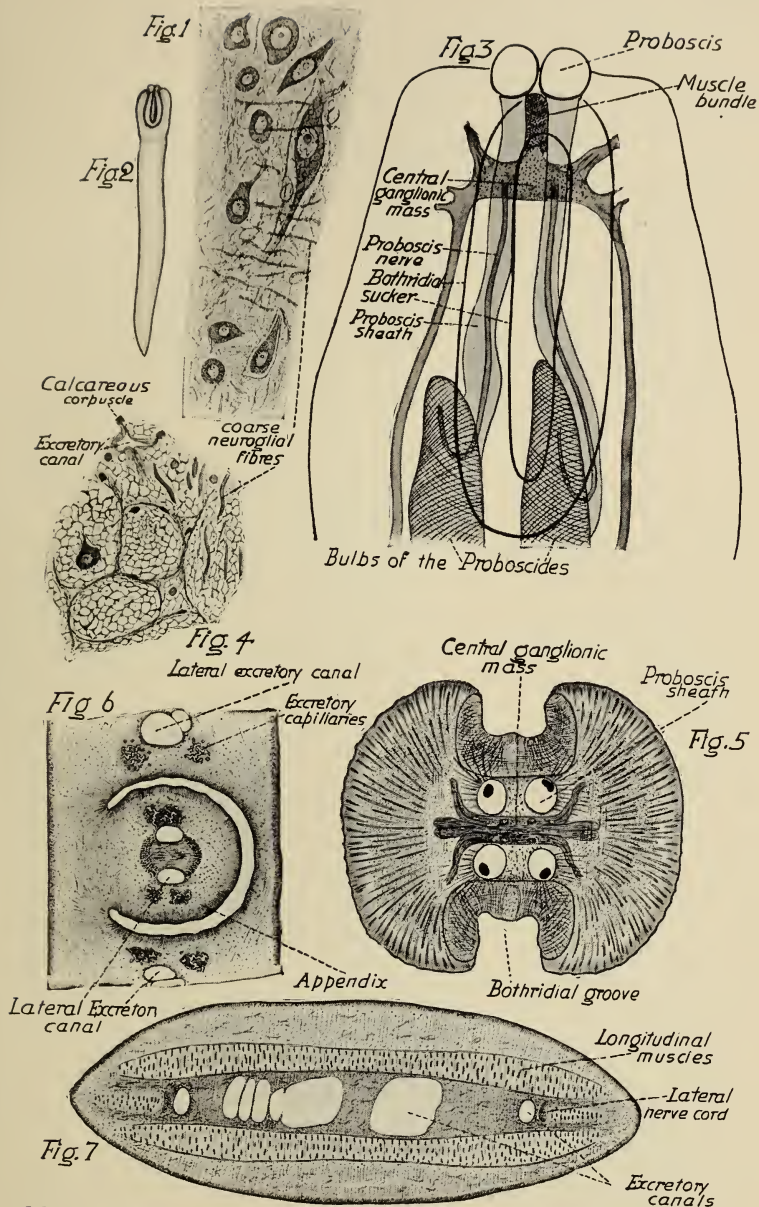
- Fig. 1. Ray with ectasia of the sensory canals. Ventral view of head. The canals are cut open on the left, but are left untouched on the right side. The intra-cystic growths have been removed on the left side.
- Fig. 2. Dorsal view of the head. The canals are cut open, and the intra-cystic growths are present *in situ*.

(Photos. by Mr. A. SCOTT.)

PLATE V, figs. 1 and 2.

- Fig. 1. Ray with ectasia of the sensory canals. Photograph of two intra-cystic growths dissected out from the canals cut open in fig. 1, Pl. IV. Natural size.
- Fig. 2. Papillomatous growths from the snout of a Halibut; about one-half natural size.

(Photos. by Mr. A. SCOTT.)



J.J. del.

COENOMORPHUS LINGUATULA (VAN BENEDEN).



Fig. 1



Fig. 2



Fig. 3



Fig. 4



Fig. 5



Fig. 6



Fig. 7



Fig. 8

(J. J. del.)

MORBID HISTOLOGY OF FISHES.

Fig. 1

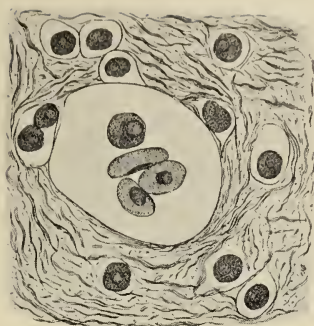


Fig. 2

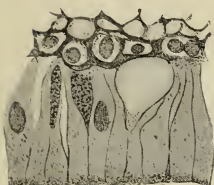


Fig. 3

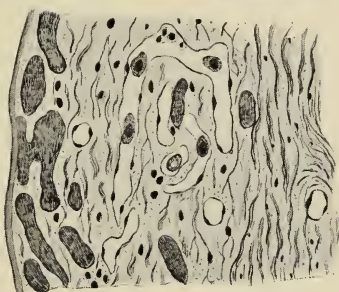


Fig. 4

Fig. 5



Fig. 6

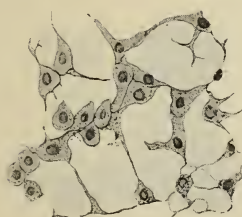


Fig. 7

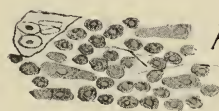


Fig. 8

(J. J. del.)

MORBID HISTOLOGY OF FISHES.



(Photos. by A. Scott.)

FIG. 1. Ventral aspect.

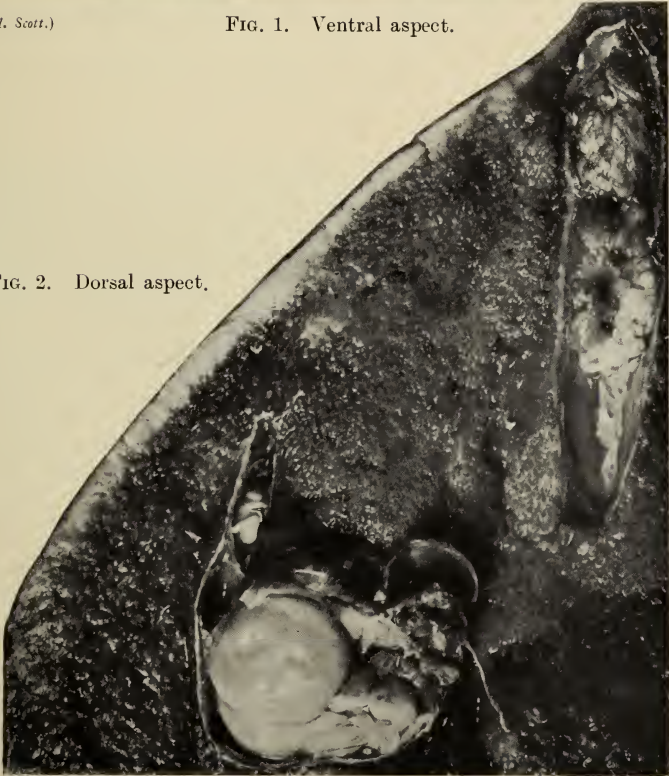


FIG. 2. Dorsal aspect.

RAY WITH ECTASIA OF THE SENSORY CANALS.



FIG. 1. Ray with Ectasia of the sensory canals. Two of the intra cystic growths.
Nearly natural size.

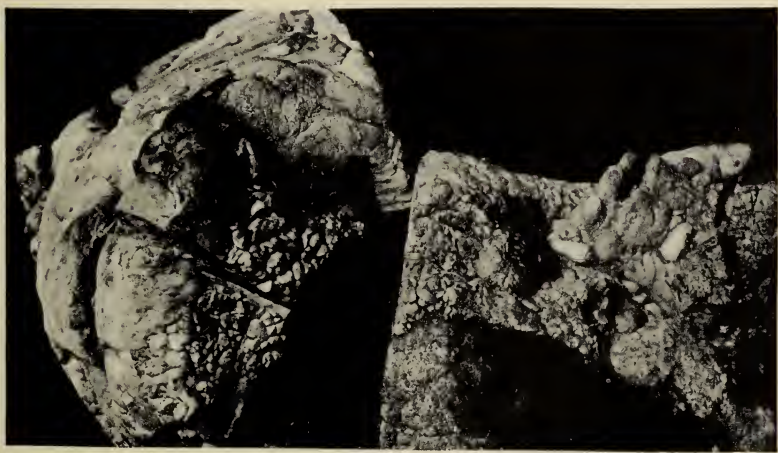


FIG. 2. Papillomatous growths from snout of halibut. Reduced about one-half.

DISEASED CONDITIONS OF FISHES.

REPORT ON THE HYDROGRAPHIC WORK IN
THE IRISH SEA DURING 1911.

BY HENRY BASSETT, JUN., D.Sc.,
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During 1911 considerable difficulty has been experienced in carrying out the hydrographic work in the Irish Sea. Samples were collected from the seven stations on the lines, Piel Gas Buoy—Calf of Man, and Calf of Man—Holyhead, on February 1st, June 12-13, and October 24-25; and from Stations V, VI and VII on December 10th. The June samples were collected as a sort of compromise for those which should have been collected in May and August, during which months it was found impossible, for various reasons, to carry out hydrographic cruises.

The observations made have, however, been sufficient to show that the state of the water in our area during 1911 was quite different from that found during the two preceding years, 1909 and 1910, and more like that found during 1907 and 1908 (with a probable difference which will be referred to presently). Here, again, we apparently have that intimate connection between the salinities (that is to say, the state of the Gulf Stream Drift) and meteorological conditions to which attention has been drawn in the last two reports. It is hardly necessary to point out that the brilliant dry summer of 1911 differed completely from the miserable wet ones of 1909 and 1910.

Table I, which summarises the salinities at the Stations, V, VI and VII from the commencement of our observations in July, 1906, is instructive. As has been shown previously, these are the only ones of our Stations which are affected by the Gulf Stream Drift—the effect of

the latter at the other Stations being entirely masked by inflowing fresh water. Even Station VII, which is nearest the Welsh coast, is liable to be affected by the fresh coastal water, which probably accounts for the somewhat irregular results at this Station.

On looking through Table I one is struck by the remarkable similarity in the salinities at any particular Station and at corresponding periods of the year during the years 1907, 1908 and 1911. Stations V and VI are particularly striking in this respect, while the results for Station VII are somewhat less regular.

Similarly, the very close agreement of the salinities throughout the two years, 1909 and 1910, is worthy of particular note.

It certainly looks as though years when the salinities are low during the winter months at these three hydrographic stations (and probably at others as well), are years when the following summer months are unusually gloomy and wet. During such years it would appear that the Gulf Stream Drift is so feeble that the maximum salinity is not reached before May, and is then a good deal lower than usual. In other years the maximum salinity occurs several months earlier, and is a good deal more pronounced.

In 1911, which was, of course, a quite abnormal year, the maximum seems to have been reached at the very beginning of the year or even at the end of December, 1910. I believe that this is quite unusual in our area, and am inclined to associate it with the brilliant character of the summer of 1911.

Unfortunately, we have no data for December 1906, 1907, 1908 and 1909, but from the general character of the salinities during those years I believe that the salinities during December were slightly lower than those

found during November. This is what we have found to be the case in December, 1911, and it represents, I believe, the more usual state of affairs. Since, moreover, the high values of the salinities on February 14th, 1912, at the three chief stations (Station V, 34.65; Station VI, 34.47; Station VII, 34.38) indicate that they will almost certainly prove to be the maximum values at these stations for 1912, I have little hesitation in saying that the summer of 1912 will probably be like neither the brilliant dry one of 1911 nor the gloomy wet ones of 1909 and 1910, but just one of the somewhat variable and uncertain summers which are usually experienced in this country.

It is worthy of note that the salinities found during February, 1912, are the highest we have observed since commencing hydrographic observations in 1906. This indicates the presence of an unusual amount of warm water in the North Atlantic, and it is probable that the wet and unsettled character of the winter and spring months which have just passed is directly traceable to this, for the presence of warm water is regarded by hydrographers as favourable to the formation of cyclones.

Further work is still needed to show if the intimate connection, which seems to exist between the state of the Gulf Stream Drift and the succeeding summer weather, will hold over a long period. The question is so important that it would be a great pity if anything should prevent its accomplishment, and if it is not possible for the Fisheries' Steamer to collect the water samples regularly, then some other arrangements ought to be made.

Mr. J. Johnstone, B.Sc., collected the water samples and made the temperature observations as usual during 1911, while I have carried out the

salinity determinations as in previous years. The results are collected in the tables, which follow, where T° , $Cl^{\circ}/_{\infty}$, $S^{\circ}/_{\infty}$, and σ_t have the usual meanings. Monthly means of daily sea temperatures at the surface, for the years 1910 and 1911, are also given. These are calculated from figures supplied by the Meteorological Office.

TABLE I.

Station.	Year.	Jan.- Feb.	May.	July- Aug.	Oct.- Nov.	Dec.
V 53° 53' N. 4° 46' W.	1906	—	—	34.24	33.93	—
	1907	34.40	34.33	34.13	34.00	—
	1908	34.27	34.25	34.05	34.05	—
	1909	33.86	34.20	34.11	33.82	—
	1910	33.86	34.07	34.00	33.84	34.43
	1911	34.27	34.27 (Jun. 13)		34.09	34.00
VI 53° 43' N. 4° 44' W.	1906	—	—	34.16	34.02	—
	1907	34.33	34.29	34.09	33.95	—
	1908	34.40	34.14	34.14	34.18	—
	1909	33.93	34.22	34.11	33.95	—
	1910	33.93	34.18	34.02	34.04	34.33
	1911	34.36	34.23 (Jun. 13)		34.14	34.05
VII 53° 33' N. 4° 41' W.	1906	—	—	34.13	34.04	—
	1907	33.75	33.96	33.98	33.73	—
	1908	34.38	34.05	34.14	34.02	—
	1909	33.98	34.14	34.00	33.84	—
	1910	33.73	34.13	33.89	34.04	34.16
	1911	34.07	34.05 (Jun. 13)		33.78	33.77

February 1, 1911.

Stations I. to IV. Surface observations only.

Station.	Time.	T°	$Cl^{\circ}/_{\infty}$	$S^{\circ}/_{\infty}$	σ_t
I. 54° N. ; 3° 30' W.	10.45 a.m.	5.0	17.67	31.92	25.26
II. 54° N. ; 3° 47' W.	11.40 a.m.	5.5	18.18	32.84	25.83
III. 54° N. ; 4° 4' W.	12.30 p.m.	6.6	18.66	33.71	26.48
IV. 54° N. ; 4° 20' W.	1.30 p.m.	7.0	18.85	34.05	26.69

Station V. (2.40 p.m.), $53^{\circ} 53' N.$; $4^{\circ} 46' W.$ Depth of Station, 43.9 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	7.7	18.97	34.27	26.77
30	7.7	18.97	34.27	26.77
78	7.7	18.97	34.27	26.77

Station VI. (3.55 p.m.), $53^{\circ} 43' N.$; $4^{\circ} 44' W.$ Depth of Station, 69.5 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	7.75	19.02	34.36	26.83
30	7.75	19.02	34.36	26.83
65	7.75	19.02	34.36	26.83

Station VII. (4.50 p.m.), $53^{\circ} 33' N.$; $4^{\circ} 41' W.$ Depth of Station, 43.9 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	7.30	18.86	34.07	26.67
30	7.35	18.85	34.05	26.64
44	7.35	18.86	34.07	26.66

June 12 to 13, 1911.

Station I., 12/6/11 (4.5 p.m.), $54^{\circ} N.$, $3^{\circ} 30' W.$ Depth of Station, 23.8 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	15.1	18.03	32.57	24.10
22	11.3	18.28	33.03	25.21

Station II., 12/6/11 (6.40 p.m.), 54° N. ; 3° 47' W. Depth of Station, 32 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	14.95	17.98	32.48	24.06
28	10.5	18.51	33.44	25.67

Station III., 12/6/11 (7.30 p.m.), 54° N. ; 4° 4' W. Depth of Station, 38.4 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	14.2	18.34	33.13	24.72
35	10.95	18.66	33.71	25.73

Station IV., 12/6/11 (8.35 p.m.), 54° N. ; 4° 20' W. Depth of Station, 42.1 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	13.05	18.52	33.46	25.21
39	10.75	18.80	33.96	26.03

Station V., 13/6/11 (10.40 a.m.), 53° 53' N. ; 4° 46' W. Depth of Station, 82.4 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	10.2	18.97	34.27	26.37
30	9.7	18.96	34.25	26.44
70	9.7	18.96	34.25	26.44

Station VI., 13/6/11 (11.45 a.m.), 53° 43' N.; 4° 44' W.
Depth of Station, 86 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	10.8	18.95	34.23	26.24
30	10.35	18.94	34.22	26.30
70	10.35	18.95	34.23	26.32

Station VII., 13/6/11 (12.35 p.m.), 53° 33' N.; 4° 41' W.
Depth of Station, 54.9 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	11.4	18.85	34.05	25.98
30	10.9	18.84	34.04	26.06
50	10.9	18.85	34.05	26.07

October 24 to 25, 1911.

Stations I to IV., 24/10/11. Surface observations only.

Station.	Time.	T°	Cl°/∞	S°/∞	σ_t
I. 54° N.; 3° 30' W.	1.35 p.m.	12.4	18.24	32.95	24.95
II. 54° N.; 3° 47' W.	2.35 p.m.	11.8	18.67	33.73	25.66
III. 54° N.; 4° 4' W.	4.30 p.m.	11.9	18.74	33.86	25.74
IV. 54° N.; 4° 20' W.	5.30 p.m.	12.8	18.85	34.05	25.72

Station V., 25/10/11 (10 a.m.), 53° 53' N.; 4° 46' W. Depth of Station, 71 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	12.85	18.87	34.09	25.74
30	12.75	—	—	—
66	12.75	18.87	34.09	25.76

Station VI., 25/10/11 (11 a.m.), $53^{\circ} 43' N.$; $4^{\circ} 44' W.$ Depth of Station, 73 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	13.2	18.90	34.14	25.53
30	13.1	—	—	—
70	13.1	18.90	34.14	25.73

Station VII., 25/10/11 (12 noon), $53^{\circ} 33' N.$; $4^{\circ} 41' W.$ Depth of Station, 62 metres.

Depth (metres)	T°	Cl°/∞	S°/∞	σ_t
0	13.3	18.70	33.78	25.41
30	13.2	—	—	—
58	13.2	18.70	33.78	25.43

December 10, 1911.

Stations V., VI., and VII. Surface observations only.

Station.	Time.	T°	Cl°/∞	S°/∞	σ_t
V. $53^{\circ}53'N.$; $4^{\circ}46'W.$	1.4 p.m.	—	18.82	34.00	—
VI. $53^{\circ}43'N.$; $4^{\circ}44'W.$	12.4 p.m.	9.8	18.85	34.05	26.26
VII. $53^{\circ}33'N.$; $4^{\circ}41'W.$	11.4 a.m.	8.8	18.69	33.77	26.20

Mean Monthly Temperatures at various Light-Vessels in 1910 and 1911.

	1910.					1911.				
	Carnarvon Bay.	Liverpool North-West.	Morecambe Bay.	Bahama Bank.	Solway.	Carnarvon Bay.	Liverpool North-West.	Morecambe Bay.	Bahama Bank.	Solway.
January	8.05	5.83	4.86	6.50	4.60	9.82	6.21	5.61	6.66	4.45
February	7.49	5.66	4.86	5.89	4.60	8.33	5.83	5.45	6.38	4.45
March.....	7.38	6.36	5.89	6.94	6.38	8.05	6.44	6.10	6.44	5.83
April	8.28	7.50	7.05	7.50	7.60	8.21	6.55	6.83	7.28	7.28
May	9.53	9.48	9.70	9.65	10.56	9.26	10.06	11.22	10.23	11.83
June	11.16	12.76	13.10	12.38	14.60	11.61	13.60	14.15	13.18	15.32
July	12.48	15.10	15.1	13.93	15.10	13.28	15.94	16.38	14.71	16.77
August	13.55	15.26	15.66	15.26	15.82	15.38	—	18.22	16.61	17.49
September	14.10	14.71	14.76	14.94	14.32	14.71	—	16.32	15.88	15.43
October	14.10	13.15	12.88	13.27	11.94	13.83	—	12.44	13.17	11.39
November	11.06	8.76	8.22	9.48	6.49	11.83	8.94*	8.94	9.61	7.72
December	9.71	7.34	6.38	8.22	5.99	9.94	8.22	7.66	8.55	6.39

* Mean of period 17-30 Nov. There are no observations for Aug., Sept., Oct., and 1-16 Nov.

Mean Monthly Temperatures : Carnarvon Bay Light-Vessel.						Liverpool N.W. Light-Vessel.				
	1907.	1908.	1909.	1910.	1911.	1907.	1908.	1909.	1910.	1911.
January	8.06	8.11	8.6	8.05	8.83	5.61	5.77	6.36	5.83	6.21
February	7.06	7.00	7.49	7.49	8.33	4.44	5.28	5.72	5.66	5.82
March	7.00	6.83	7.38	7.38	7.78	6.11	5.55	5.12	6.36	6.43
April	7.61	7.22	8.50	8.28	8.21	7.43	6.67	7.28	7.50	6.55
May	8.89	8.66	9.59	9.53	9.26	9.82	9.59	10.40	9.48	10.06
June	10.29	10.84	11.17	11.16	11.61	—	12.88	12.60	12.76	13.60
July	12.16	12.60	12.78	12.48	13.28	13.89	15.10	14.77	15.1	15.94
August	13.00	13.66	13.99	13.55	15.38	15.10	15.05	15.55	15.26	—
September	13.89	12.37	14.26	14.1	14.71	14.54	12.43	14.71	14.71	—
October	13.00	13.33	13.00	14.1	13.83	12.78	12.78	13.18	13.15	—
November	11.99	12.37	11.11	11.06	1.83	10.40	10.17	9.26	8.76	8.94*
December	10.12	11.06	9.44	9.71	9.94	8.21	6.32	7.06	7.34	8.22

* See note on page 153.

NOTE ON AN ULCERATIVE DISEASE OF THE
PLAICE.

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AND

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Liverpool.

(With Two Plates.)

HISTORY AND CHARACTERISTICS.

For some years past the stock of spawning plaice at the Port Erin Hatchery has been subject to a disease, apparently infectious, which has done much damage.

The plaice are kept in two large open-air ponds, which together occupy a space 90 feet long by 50 feet wide, with a total capacity of about 130,000 gallons. The number of fish in the ponds varies from about 300 to 400 or more; the average number is roughly 350. Disease seems to have made its appearance first in 1905; at any rate no diseased fish were observed before that year. It has been more or less constantly present ever since; in 1910 there was less disease than in any other year since 1905, but in 1911 many of the fish in the pond were affected.

The disease is characterised by superficial ulceration (see Pl. I), which seems to have no very characteristic site, though possibly ulcers are more common on the top of the head and at the base of the tail. Still we have seen ulcers on so many different parts of the surface that we cannot regard any position as typical. The ulcers are of a spreading and sloughing type, leading to considerable destruction of tissue and often extending down to the muscular layer. They vary in size up to about

3 cm. in diameter, with a well marked edge and a red injected base. The lesion commences as a small inflamed area of skin; this increases in size and ultimately the skin breaks down to form an ulcer which gradually enlarges. As a rule more than one ulcer are present, but they are never numerous. The fish dies eventually in an emaciated condition, but infected fish have been observed to feed freely, and even badly infected fish may retain their muscular strength to a surprising extent.

Microscopically, a section through an ulcer reveals great destruction of tissue, the base being covered with débris. Beneath this are many swollen capillaries filled with blood corpuscles, accounting for the injected appearance which the base presents to the naked eye. No bacteria were to be seen in the tissues. In the outer layer of dead cells and débris were numerous slender Gram-negative bacilli; these, however, we regard as coming from outside, and probably not pathogenic.

BACTERIOLOGICAL INVESTIGATION.

The material for this investigation was derived from:—

- (1) A fish (I) found dead in the pond and sent to Liverpool, examined when two days dead. Cultures were made on to nutrient gelatine from heart blood, liver, and from a large ulcer.
- (2) Cultures were made by Dr. Dakin at Port Erin. (A) from the ulcers of two living fish (II and III) on gelatine, and (B) from the heart blood and liver of the same two fish, also on gelatine. All these cultures were at once despatched to Liverpool.
- (3) A sample of water from the ponds.

Ulcers.—Scrapings of four ulcers from three fish were examined. The gelatine cultures obtained were diluted with normal saline and plated out upon gelatine with a view to discovering whether the original cultures were pure or a mixture of organisms.

From I a pure culture was obtained; the ulcers of II and III produced a mixed culture of two organisms, one of which was identical with that from I. All liquefied gelatine within forty-eight hours.

Heart Blood.—From I a bacillus was obtained which was identical with the bacillus of the ulcers. From II was obtained a growth of a bacillus which was at once differentiated from the others by its inability to liquefy gelatine. No growth was obtained from III.

Liver.—I gave a bacillus identical with that derived from the ulcer and blood of the same fish. No growth was obtained from II, and no culture was taken from the liver of III.

Water.—Two distinct organisms were isolated. The one closely resembled the organism obtained from the ulcer of I and one of the organisms from the mixed cultures given by the ulcers of II and III. The other resembled the non-liquefying bacillus obtained from the heart blood of II.

Three organisms therefore have to be described:—

Bacillus A: derived from the ulcers of all three fish, and from the liver and heart blood of I. Upon agar this gives a raised yellowish growth with clear transparent edges. It grows well upon all ordinary solid media at cold incubator temperature or at room temperature. At 37° C., in the warm incubator, the growth is scanty, almost invisible on the few media upon which it exists, and it loses its viability in two or three days at this temperature. It has little or no action upon the common

sugars in 0·5 per cent. solution in peptone broth, and milk is unchanged after seven days' incubation. Gelatine is liquefied in thirty-six hours. Morphologically it is a stout curved bacillus which shows longer straight forms. It is Gram-negative.

Bacillus B: derived from the ulcers of II and III, and identical with the liquefying bacillus obtained from the water sample.

This organism is closely allied to *A* in its characteristics as regards growth at different temperatures. It grows best at 20° C., less well at room temperature, and apparently not at all at 37° C. Even at room temperature it loses its viability upon solid media in 5-6 days and must be frequently sub-cultured. Its appearance on solid media is very like that of *B. coli*, clear, transparent, only becoming at all clouded at the bottom of the tube. It liquefies gelatine within forty-eight hours. Morphologically it is a slight slender bacillus, about the same length as *A*, and also shows some tendency to curve. It is Gram-negative.

Bacillus C. This differs from *A* and *B* in not liquefying gelatine. It was derived from the heart blood of II and from the sample of water. In shape and size it resembles *A*, and is Gram-negative.

Smears were made from ulcer, liver, and blood of I, and the accompanying micro-photographs (Pl. II, figs. 1-3) show the distribution of the bacilli in these. Since this fish had been dead at least two days when examined, the tissue might have become invaded with intestinal organisms and the bacilli seen may represent secondary invaders. But it is significant that the cultures obtained from this fish correspond with those from the others. Further, no bacilli were observed in smears made from liver and blood of two other fish, not ulcerated, which

were also sent to Liverpool after being found dead in the pond.

Bacillus A has some characters in common with *Bacillus Salmonis-pestis*, which, however, is not viable in sea-water. Whether any of these bacilli thus isolated have an actual connection with the ulceration can only be determined by experiments, such as those of Hume Patterson on *B. Salmonis-pestis*, with fish living in water to which cultures of the organisms have been added. We hope to carry out experiments of this nature with all three bacilli and to incorporate the results in a future report.

CONCLUSIONS.

When the disease first appeared in 1905 Johnstone* regarded it as due to an entomophthoran fungus, apparently closely related to the genus *Conidiobolus*, which he discovered in the viscera (liver, kidney, and mesenteries) of some of the affected fish. He notes the characteristic ulceration of the surface of the body. This fungus we believe to have been a secondary condition. The fish which died in 1905 were affected with the same superficial ulceration as those which we have examined, and this condition has been constantly present among the Port Erin fish ever since. None of the fish which we have seen have shown any signs of fungus in any of the viscera, and it was by no means constantly present even in the fish which Johnstone examined. He remarks that though many of the dead fish showed no signs of fungus, the surface lesions were of the same nature in all the fish. He was unable to find any trace of fungus in the ulcers. We believe, therefore, that this fungus was a secondary condition, the case being comparable to that of salmon disease. This fungus appears to have died out.

* Rep. Lanc. Sea-Fish. Lab. XIV, 1905 (1906), p. 179.

Anderson* has recently described a very similar disease among whiting and plaice from Bay of Nigg, Aberdeen. He gives the following description of the ulcers on the plaice:—"They commenced in paling and desquamating spots, spreading rapidly to form large ulcerated areas, often one to two inches in diameter. The edges of the ulcers were deeply undermined, the base often extending down to the muscular tissue. . . . The base of the ulcers often presented a very injected appearance." This would apply equally well to the Port Erin fish.

The disease described by Anderson was apparently more virulent than the present one, though its virulence seems to have decreased towards the end of the period he mentions; thus during September and October 187 dead plaice were removed from the pond, while from that until December 26th only 13 more were found.

Anderson regards the disease as some form of septicaemic poisoning, possibly caused by sewage-borne organisms. The pathogenic organism seems to have been the *Staphylococcus pyogenes aureus*, which was obtained from all the superficial lesions examined and from the blood in most cases. In this respect, therefore, it differs from the disease now described.

The Port Erin disease cannot be due to sewage pollution, as the water is remarkably pure, and the fish are obtained from areas where there can be no question of pollution. These septicaemic conditions may be due to various organisms acting on fish which are under abnormal conditions. As regards fresh-water fish, Ceresole* has described a bacillus causing ulcerative septicaemia in gold-fish (*Carrassius auratus*).

* 28th Ann. Rep. Fish. Bd. Scotland, Pt. III, 1911.

† Zentr. fur Bakt. und Parasitenkunde, Bd. 28, 1900.



FIG. 1.

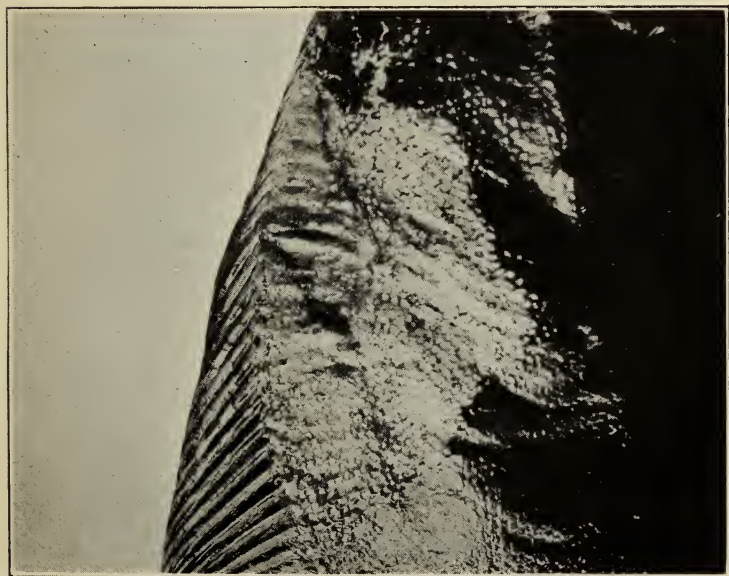
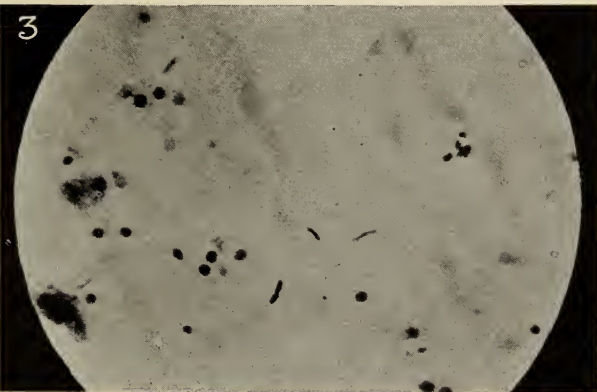
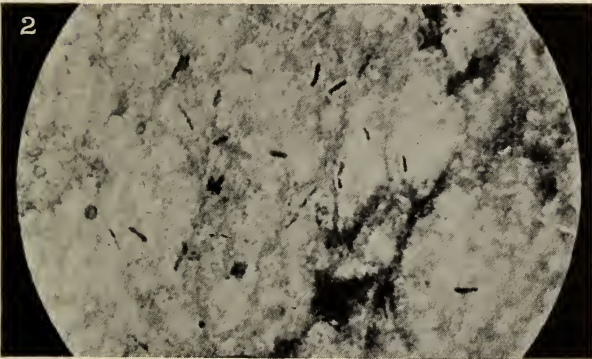
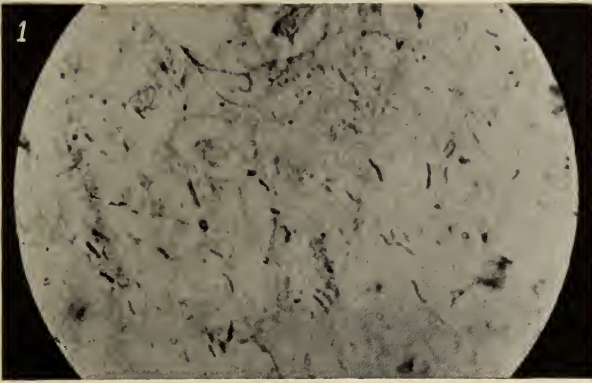


FIG. 2.

DISEASED PLAICE.



BACILLI FROM DISEASED PLAICE.

It has been suggested that these lesions are due to accidental injuries received either in the trawl or in the storage pond. While it is not impossible that such injuries may be a slight contributing factor, we cannot regard them as the cause. If they were, it would be very difficult to account for the absence of disease prior to 1905, though the conditions of capture and storage have undergone no change since that year.

Taking all the evidence into consideration we believe, though we do not consider it definitely proved as yet, that this disease is bacterial and probably connected with one of the three bacilli which we have described. The condition is, then, a septicaemia strictly comparable to those described by Anderson and Ceresole. All the evidence appears to us to point to this conclusion.

EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1.—Head of diseased Plaice showing ulceration.

Fig. 2.—Another specimen showing ulceration at base of dorsal fin.

PLATE II.

Fig. 1.—Smear from an ulcer of Fish I, showing the Bacilli. From a micro-photograph.

Fig. 2.—Smear from liver of Fish I. From a micro-photograph.

Fig. 3.—Blood-smear from Fish I. From a micro-photograph.

PUBLIC HEALTH BACTERIOLOGY IN THE
LANCASHIRE SEA FISHERIES DISTRICT.

By Professor W. A. HERDMAN, D.Sc., F.R.S.

After twenty years of scientific work on shell-fish and sewage in connection with the Lancashire Sea Fisheries Committee, and just when the promised Government grant will enable that work to be extended and put on a permanent basis for the future, it seems, now, the appropriate time to summarise what has been done in the past and to state the views and the actions which that work has led up to.

The Lancashire and Western Sea-Fisheries Committee has jurisdiction over the largest shell-fish producing areas in the British Isles; and the Scientific Staff of this Fisheries District can claim to have been pioneers in the application of scientific methods of research to these great shell-fish beds, and especially in the investigation of sewage pollution as a possible danger to the public health. The connection between the consumption of polluted shell-fish and epidemics of enteric disease is now too well established to need further demonstration. It is admitted in the Reports of the Local Government Board and of the Royal Commission on Sewage Disposal and in many other authoritative works. The chances of sewage pollution on our populous shores are, and have been for the last few decades, constantly increasing; and some sea-side localities are certainly, in their present condition, quite unfit for the cultivation or storage of shell-fish intended for human food. On the other hand the magnitude of the shell-fish industries around the British Islands, the number of men and their families engaged directly or indirectly, and the value of these food supplies to the

nation must not be forgotten. Here we have, on the one hand a growing menace to the public health, and on the other the threatened reduction, if not destruction, of a great industry. The prospects of averting, or at any rate of minimising, both these evils depend upon a more intimate and accurate knowledge of the connection between the shell-fish and the disease germs, and the relation of both to their common environment; and the opportunity has thus been given for scientific investigations on a large scale and leading to results of far-reaching importance.

The local bacteriological work on shell-fish was begun in the spring of 1895, when my late colleague Professor (afterwards Sir Rubert) Boyce was visiting me at Port Erin and we joined in work, both on the shore and in the Biological Station, on the bacteriology of re-laid American Oysters (obtained from Liverpool and Fleetwood) under various conditions. These experiments showed that oysters laid down only a short distance apart differed enormously in their bacterial contents. Taking *Bacillus coli* as an example, a certain standard culture made from an oyster laid near the mouth of a small sewer gave 17,000 colonies, while a similar culture from those laid a little distance off in purer water had only 10 colonies. This work at Port Erin formed the subject of a paper read by Professor Boyce and myself before Section D. (Zoology) at the Ipswich meeting of the British Association in September, 1895. Shortly after this, in October, 1895, public attention was directed to the subject in a sensational manner by the serious outbreak of enteric fever amongst those at the Stirling County ball, who had unwisely supped on oysters which were afterwards proved to be in a very doubtful condition. This occurrence was followed by a wide-spread "oyster scare" which led to a

comprehensive investigation of shell-fish beds and layings round the coasts of England and Wales, and the publication, in the following year (1896), of a Local Government Board Report by the late Dr. H. Timbrell Bulstrode, with an additional Report on the bacteriology by Dr. E. Klein.

In the meantime Professor Boyce and I continued our investigations on the bacteriology of shell-fish under various conditions, both at Port Erin and also in the Zoological and the Pathological laboratories of the University of Liverpool, with the help of several colleagues, and read successive reports at the Liverpool (1896), the Toronto (1897) and the Bristol (1898) meetings of the British Association. We also published a paper on an unhealthy condition of American oysters associated with the accumulation of copper in the leucocytes (Proc. Royal Society, 1897); and finally incorporated all our results in a larger work "Oysters and Disease," issued as a "Lancashire Sea-Fisheries Memoir" in 1899.

One of our first objects in all this work had been to determine whether sewage bacteria, such as the *Bacillus coli communis* and *B. enteritidis sporogenes*, occurred in the alimentary canal of the living oyster taken fresh from the beds—apart from what might be found in stored oysters obtained in towns from markets and shops. We also, in order to trace the history of the bacteria in the shell-fish, infected oysters kept under experimental conditions, and examined these after fixed intervals of time, and so were able to show that the typhoid organism, for example, could be recovered from our experimental oysters up to 10 or 12 days after infection, and even under some conditions up to three weeks from the sea-water associated with the oysters.

In the 1896 report (British Association—Liverpool meeting) we dealt mainly with the bacteriology of the

oyster and the behaviour of *Bacillus typhosus* in sea-water and in the body of the shell-fish, and although we found that we were, on occasions, able to recover our experimental bacilli up to the twenty-first day from infected sea-water kept in the cold, still in most cases they disappeared before that time. At any rate there appears to be no multiplication either in the sea-water or in the body of the shell-fish—on the contrary, we found, as others* have done, that in clean sea-water the *Bacillus typhosus* rapidly decreases in numbers.

In further experiments where the infected oysters were subjected to a running stream of clean sea-water, the results were definite and uniform. There was in all cases a great diminution or total disappearance of the typhoid organism in from one to seven days. The stream of water enables the mollusc to purify its gills and alimentary canal, and so free itself from the results of sewage pollution; and we found that in the great majority of cases most of the bacteria were in fact cleared out in the course of the first three days.

A considerable amount of attention was also given in these reports to other diseased conditions of the oyster, and to the presence of copper and iron in abnormal quantities in the tissues of shell-fish from some localities.

Some of the earlier Lancashire Sea-Fisheries Laboratory Reports, from 1895 onwards, gave brief notes of the work that we were doing on the bacteriology of the oyster, covering much the same ground as the reports that were made to the British Association; and as a general summary, in the Lancashire Report for 1903 I had an article, entitled "Sewage and Shell Fish," which discussed the evidence that had been accumulated locally

* De Giaksa has shown that even if pathogenic bacteria are able to live for a time in sterilised sea-water they soon die off in the struggle for existence with the bacteria of normal sea-water.

(and which had been laid before the Royal Commission on Sewage Disposal* then sitting) in regard to the serious contamination by sewage of some of the shell-fish beds of the district. This article included the report by the late Mr. R. A. Dawson, then the Superintendent of the Fisheries District, on the mussel beds of our coasts in regard to danger of pollution by sewage, revealing a very serious state of affairs in some parts of the district.

In connection with this article in the 1903 Report we have the first of Mr. Johnstone's papers on the bacteriology of samples of mussels from the Mersey Estuary. This report was submitted to the Lancashire Sea Fisheries Committee and was also communicated to the Board of Agriculture and Fisheries at their request. Mr. Johnstone demonstrated the presence in these mussels of bacilli which were regarded as affording certain evidence of sewage pollution. This investigation was followed by the examination of samples of mussels from various other beds in the district; and in all these cases in which sewage contamination was reported upon from this Laboratory we did not rely upon the bacteriological evidence alone—that evidence throughout has been used as an important corroboration, but not as the sole proof.

In the fourth report of the Royal Commission on Sewage Disposal, 1904, the Commissioners state that they would not be justified in recommending that the closing of a shell-fish bed or laying should depend as a matter of routine on the results of the bacteriological examination, and this is very much the conclusion at which Mr. Johnstone and I had then arrived as the result of our experience, and it is the opinion that I gave in my evidence before the Royal Commission. In 1904 I expressed my views on the question of samples as follows:—

* See Fourth Report of the Commissioners, Cd. 1884, p. 90, 1904.

“ In taking samples of suspected shell-fish I would attach great importance to personal supervision by a scientific or fisheries expert. The samples should obviously not be taken by the parties interested, and they should not be taken by disinterested, but untrained collectors who may miss seeing some qualifying factor or some important piece of evidence. A knowledge of the local conditions, of the influence of tidal and other currents, and of prevalent winds, may be of great value in judging of the presence and extent of pollution, and of the parts [of the bed] liable to be affected at a particular time of day, or of the month. Consequently a personal examination of the locality by a scientific man is always important. Samples from various parts of the same bed may have to be taken at different states of the tide, and these should be chosen with knowledge and discrimination.

“Any additional evidence that can be obtained from an inspection of the physical and biological conditions on the bed is all the more important because of our want of exact knowledge as to the meaning and value of some bacteriological results. The topographical observations and the laboratory work ought always to be considered together, and must be regarded as parts of the same investigation conducted by the one Authority. The bacteriological examination may at once confirm the field-work in such a manner as to leave no doubt as to the purity or pollution of the locality, or it may give useful indications which suggest the necessity for further observation of the local conditions. It may also give a measure of the amount of pollution. The question has been raised as to whether it is possible to fix a standard of pollution which should be regarded as dangerous to health. Can we say that all samples yielding say 10, or say 20 *B. coli* per c.c. must be condemned, but that those showing less than say 5 per

c.c. may be tolerated? Before answering such a question we must have further investigations. There are still too many of the points involved which are left in doubt. For example, we cannot be certain that all samples yielding 10 *B. coli* per c.c. are equally dangerous. Even if we assume (as we probably may safely do) that pure oceanic sea-water is free from *B. coli* and allied organisms, and that these are to be taken as an indication of some sewage contamination, we do not know how remote in time the pollution may have been and how comparatively harmless from a pathogenic point of view it may have become. It is possible, or even probable, that *B. coli* may be distributed to considerable distances in the excreta of fish and sea-birds, possibly with some modification. Then again, the bacteriology of the shrimp's alimentary canal requires examination, and we may add the fishes that feed upon the shrimp. There are also other sewage feeding invertebrates that may conceivably pass on some organisms and not others, and may favour the distribution of *B. coli* under circumstances that deprive its presence of any special [pathogenic] significance.

"I am not arguing against the value of bacteriology, but against a possible abuse of the method, and in favour of a much wider investigation in which the laboratory work will in all cases be supplemented, guided and inspired by the marine biologist's work in the field. The case of each estuary, bed, or laying must be regarded as a separate problem to be solved with a full knowledge of all the local conditions."

In 1905 Mr. Johnstone reported to our Scientific Sub-Committee on the detailed examination of the Llan-fairfechan mussel bed in the Menai Straits. He and Dr. Jenkins personally collected samples for analysis and studied carefully the topographical relations of the shell-

fish on the bed in relation to sewage outflows and dispersal and defects in the drainage arrangements. As a result of the examination it was found that *Bacillus coli* could be isolated from the majority of the mussels examined. The presence of this microbe usually indicates the contamination by faecal matters of the shell-fish in which it is found. But unhappily, this organism must now be regarded as present almost everywhere in shell-fish bedded on our coasts, and its significance lies not so much in its mere presence as in its relative abundance. It will be seen from the detailed results stated in the Report that *B. coli* was very abundant in several of the mussels examined: these were the ones collected from the piles in the neighbourhood of a break in the pipe. Two mussels in the sample were quite sterile, and in one or two others the microbe was present in very small quantity; these latter shell-fish were collected from the piles some considerable distance from the break in the pipe. Only in one or two of the mussels examined was the degree of pollution at all excessive.

In this case Mr. Johnstone points out that "it is probable that the faulty condition of the sewer pipe is the cause of the greater part of the pollution of these mussels. The eddies caused by the tide round the piles have excavated a shallow gutter directly beneath the sewer pipe. As the tide lays bare the sands, this gutter becomes filled with a mixture of sea-water and sewage flowing from the break in the pipe. Then when the tide begins to flow, some of this water becomes washed up against the mussels on the piles, and the former become polluted. If the sewer pipe were in proper repair, so that all the discharge flowed from its extremity, and still more if there were an intercepting tank at the pumping station and the sewage were only liberated on the ebb tide, the

pollution of the mussels would be very slight, and would be due only to the slight amount of general pollution of the sea caused by the sewage from the towns at the entrance to the Menai Straits.”

These conclusions, at which Mr. Johnstone arrived from an examination of the conditions on the ground quite as much as from the bacteriological investigation in the laboratory, illustrate the value of a personal topographical inspection by a competent marine biologist.

In continuation of the experiments which I had begun with Prof. Boyce, on cleansing shell-fish from sewage bacteria by means of currents of water, I asked Mr. Andrew Scott, in 1904, to re-investigate the matter with polluted mussels at the Piel laboratory in the Barrow Channel. Mr. Scott used mussels taken from a sewage polluted area, and after ascertaining that they contained large numbers of sewage bacteria, he exposed them to currents of 1.75, 3.3 and 6 gallons of clean sea-water per hour. The results of a number of experiments showed a rapid diminution in the number of bacteria as measured by the colonies produced in Petri dishes of neutral-red bile salt agar. At the commencement of the experiment the control mussels showed numbers like 1200, 1500 and 2000 colonies, and at the end of from 24 to 48 hours numbers such as 30, 20, and 10 colonies only were found.

In illustration of the importance of understanding the tidal and other currents before collecting samples of water for bacteriological examination, take the following series of observations made by Mr. Johnstone. In May, 1908, he made comparative cultures of samples of water taken from the Barrow Channel every two hours, and obtained the results given in the following table, stated in number of intestinal bacteria in 2 c.c. of water:—

FLOOD TIDE WATER				EBB TIDE WATER			
5 hours before high water	...	0		6 $\frac{1}{4}$ hours before low water	...	0	
3 „ „ „	...	1		4 $\frac{1}{4}$ „ „ „	...	0	
1 „ „ „	...	0		2 $\frac{1}{4}$ „ „ „	...	200	
				$\frac{1}{4}$ „ „ „	...	1000+	

These investigations and results, which might be extended with advantage to other channels and estuaries, are of considerable importance. They indicate that even in an estuary which was proved to be polluted the flood tide water may be clean. A practical application of this fact is the possibility of cleansing polluted shell-fish in the flood tide water intercepted in shore ponds or tanks.

The numbers of organisms in 1 c.c. of water may vary also on different parts of a shell-fish bed as the result of amount of shelter, exposure to prevalent winds and many other local factors which must be studied on the ground by an expert and which make every shell-fish bed an independent problem to the marine biologist. Consequently, it is sometimes possible to collect samples of relatively pure and of highly polluted mussels from neighbouring parts of the same bed. Mr. Johnstone has dealt with these considerations in some detail in a recent paper (*Journ. of Hygiene*, February, 1910) from which I quote the following paragraph:—

“It is clear that much may depend on the precise conditions under which the sample is taken, and upon the precise spot. If this is so, then great caution is necessary in applying the results of analysis of a sample of shell-fish purchased from a market stall or shop, *to the general locality from which the molluscs are said to have been taken*. Not only so but the Report must, in justice to the fisherman, consider the length of time which has elapsed since the shell-fish were taken from the sea, and the conditions under which they have been stored. . . .

What then is to be said of the interpretation of the results of the analysis of shell-fish which may have been taken from the sea some six days before the date of the sampling, and which may have been stored in insanitary conditions in the meantime? The discovery of pathogenic organisms in such shell-fish might indeed be conclusive proof of the origin of a disease or epidemic, but the tracing of the latter to the part of the sea from which the shell-fish were alleged to have come might be erroneous. It is surely unfair to condemn a locality on the results of such an analysis made perhaps on moribund animals in which partial decomposition may have begun."

After the first few years of work (1895-99) in which Sir Rubert Boyce had collaborated, the Lancashire Sea-Fisheries investigations were left entirely to the Fisheries Laboratory in the Zoological Department, and the bacteriology of the shell-fish beds from this time onward has been in the hands of Mr. James Johnstone, B.Sc., under my general direction—and the practical work, both on the shore and in the laboratory, has always been carried out by Mr. Johnstone or under his personal supervision. Most of the Annual Reports on our Scientific Fisheries investigations for the last ten years contain papers on the bacteriology of the local shell-fish beds by Mr. Johnstone, and in addition he has carried out other inspections of suspected localities which led to private reports to the Committee not published in our Annual volume. All the "beds" and "layings" in the district have been surveyed and charted, every sewer outfall has been examined with respect to its influence on adjacent shell-fish, and systematic bacteriological analysis has been carried on every year. This constitutes a considerable mass of scientific work which has caused the Lancashire shell-fish beds to become better known bacteriologically

than those, probably, of any other part of the coast. I shall only refer now to a few of Mr. Johnstone's investigations as examples:—

In 1904, Mr. Johnstone reported on the mussel beds in the Mersey Estuary and in the Estuary of the Lune, and on the deep-sea oysters of our district. In this paper the dangerous pollution of the Egremont mussels was clearly demonstrated, amounting in some cases to about 300 colon bacilli in a drop—say one-tenth of a cubic centimeter—of the stomach contents of the shell-fish. The Rock Ferry mussel bed was also shown to be grossly polluted in some parts. The Wallasey bed, although yielding some evidence of sewage, was clearly much less polluted than in the case of the Egremont and Rock Ferry mussels.

The examination of the Lune Estuary was made at the request of the County Council; and Professor Delepine, of Manchester, also made an independent investigation and report. The results showed the presence of sewage organisms, but that compared with the Egremont mussels the pollution of the Lune mussel beds is not excessive. Finally, "deep-sea" oysters from various off-shore fishing grounds were found to be unpolluted.

In this paper Mr. Johnstone doubts the practicability of erecting a permissible standard of impurity. The deep-sea oysters would satisfy any standard, the Egremont beds would be condemned on any adequate standard, but the Wallasey beds are in an intermediate condition, and there might be difference of opinion amongst experts as to whether the standard should pass or condemn that degree of pollution.

In the Summer of 1906, Mr. Johnstone furnished a report to our Scientific Sub-Committee on the state of affairs at St. Annes-on-the-Sea, in which he showed that

this was a locality where the grave pollution of the mussel beds is due to the direction of the tidal streams. He says, "The topography of the coast, indeed, renders it impossible that these shell-fish can escape direct contamination." The actual pathogenic organism of enteric fever, *B. typhosus*, was isolated from the mussels examined from this bed.

In the same year (see our Annual Report for 1906) Mr. Johnstone commenced an extensive investigation of the mussel beds at the "Ring-Hole," and elsewhere in the neighbourhood of Morecambe, a matter of great importance on account of the various interests involved—including the transplantation of ill-nourished, stunted mussels from other localities to this more favoured spot for active growth. The bacteriological results showed that *Bacillus coli* was present in practically all the mussels examined, but Mr. Johnstone urges that to describe a mussel as dangerously polluted merely because it contains *Bacillus coli* would be quite unjustifiable. Its presence only indicates the *possibility* that the shell-fish in which it is found may, under certain circumstances, harbour strictly pathogenic organisms such as the typhoid bacillus. When the number of *Bacillus coli* in a mussel is small, then this possibility is remote. When the number is very large, or when the pollution is notorious (as in such cases as those of the mussels at Egremont, Rock Ferry, or St. Annes), then we may reasonably conclude that the shell-fish should not be used for human food. We agree with the Sewage Commissioners when they say, "If it should be seriously contended that the *mere presence* of *Bacillus coli* or coli-like microbes in an oyster should condemn it, few oysters would probably escape condemnation." The same is no doubt true of mussels.

Of course it would be desirable, were it possible, that no crude sewage, nor even purified effluent, should find its way to any shell-fish bed ; but when one considers the dense population of the littoral of Lancashire, it is evident that, with our present knowledge and appliances, the ideal of removing all sewage, so that no trace of it or of its organisms can reach the shell-fish beds, is quite unattainable.

Hitherto our bacteriological work had been mainly on Oysters and Mussels, but about this time, 1907-8, Mr. Johnstone commenced a systematic examination of the Cockle beds on the Lancashire littoral, and made various inspections, analyses and reports (see our Annual Report for 1908). The methods of observation and investigation are described in detail in order that future examinations of these and other beds in the district may be conducted on the same lines, so that the results may be comparable.

As a result, the numbers of the "coli" group of organisms per cockle, in the six chief beds examined, were found to be as follows:—

Ansdell	...	1,915	Silverdale	...	28
Formby	...	272	Flookburgh	...	17
Leasowe	...	60	Southport	...	12

The cockles from Ansdell are seriously polluted. Formby is a doubtful case, perhaps Leasowe is also ; but the others are so slightly affected that probably the few organisms present represent merely the general distribution of "coli" in our coastal waters, and have no harmful significance. A thorough investigation of the distribution of the colon bacillus in the coastal waters of the Irish Sea would be of great interest and practical value.

About this time, the late Dr. H. Timbrell Bulstrode,

of the Local Government Board, who had been interested in our earlier observations on oysters in connection with disease, now began to come into close relation with our work on mussels and cockles. He took part with Mr. Johnstone in visits of inspection to beds in Lancashire and North Wales, and came to Liverpool on several occasions to consult with us in regard to the co-relation of bacteriological and topographical evidence and the possibilities of remedial measures—a matter in which he took the keenest interest. Dr. Bulstrode's premature death last year is a severe loss to public health sanitation in connection with shell-fish, a subject he had made peculiarly his own by the two admirable Reports he prepared for the Local Government Board, the first on oysters, published in 1896, and the second on other shell-fish in 1911.

We have been in communication also in recent years with other Government Officials, and with Public Health Officers of several neighbouring towns and districts, and some of our recent bacteriological investigations were undertaken in consequence of these communications. It was, for example, a statement received from the Medical Officer of Health of an inland town that gave rise to Mr. Johnstone's report on the bacteriological condition of the mussel beds in the Estuary of the Wyre. It is clear that although the degree of pollution is not so great there as in other known cases, the examination was very desirable, and further investigation of that neighbourhood may become necessary. The importance of such work, carried out in co-operation with the Public Health Officers of the towns to which shell-fish are consigned, can scarcely be over-estimated, and it is gratifying to find that Dr. Bulstrode, in his recently published "Report on Shell-fish other than Oysters in relation to Disease" (Local Government Board, Cd. 5313, 1911), refers in

appreciative terms to the investigations on shell-fish, both under healthy and unhealthy conditions, which have been carried out by the Lancashire Sea-Fisheries Committee.

Dr. Bulstrode's companionship and co-operation in these investigations have been of great value to us, and it has been encouraging to find that we were generally taking the same view of the problems that he did, and were reporting on the various localities in very similar terms. As a final reference to his recent Report, I may point out, for the information of our local Committee, that, in discussing the possible machinery for the regulation of shell-fish areas, Dr. Bulstrode refers to the further valuable work that might be carried out by a Sea-Fisheries Committee organised for scientific research as ours is, and says: "The Officers of the Lancashire and Western Sea-Fisheries Committee have, under the guidance of the Honorary Director, Professor Herdman, F.R.S., together with Dr. J. Travis Jenkins, Mr. James Johnstone, and Mr. Andrew Scott, made a detailed survey of the shell-fish beds and areas in their district, and of the sewers and drains which discharge in their vicinity. They have also from time to time made valuable bacteriological examinations of the waters and shell-fish in different places, and have conducted experiments as regards the re-laying of shell-fish, which are likely to prove of permanent value both to the shell-fish industry itself and to the public health" (*loc. cit.*, p. 123).

This recognition of the value of the Committee's work in the Official Report of the Government Department directly concerned should encourage and stimulate those who are doing the work, and may justify the Committee in undertaking a larger expenditure on these very necessary investigations.

Turning now to the last, and perhaps the most

important piece of shell-fish work we have undertaken in connection with public health, it was as far back as the summer of 1906 that Mr. Johnstone, in consequence of information we had received as to the condition of shell-fish sent to the markets, commenced the investigation of the mussel beds in the Estuary of the Conway, in North Wales, an investigation which has been carried on intermittently until the present time, and is probably not yet finished. The Conway mussel industry is of considerable importance. Amounts of up to 6,000 cwt. per month (of the value of over £700) were sent from Conway during part of 1906, to Manchester, Leeds, Huddersfield, Halifax, Nottingham, and other inland towns.

Sewage, however, is discharged into the Estuary at Conway, and also into the river above, and there can be no doubt that a considerable degree of pollution of the mussels is present. Several outbreaks of enteric fever in inland towns have now been attributed, by Public Health Officers, to Conway mussels. Public enquiries have been held, and a great deal of further work, both topographical and bacteriological, has been done by Mr. Johnstone since his preliminary paper in our Report for 1906. Moreover, an examination of the beds was made along with Dr. Bulstrode in 1907, and along with an Inspector from the Fishmongers' Company in 1908, and our results were entirely confirmed by these independent authorities. But although the Conway mussels are undoubtedly polluted with sewage, still it must be remembered that, in all such cases, it is an unscientific and inconclusive statement to attribute enteric fever in (say) Manchester to the mussels of (say) the Conway Estuary, merely because such mussels when eaten by the patient, or when purchased in the

market, were found to be sewage-polluted and to give rise to the disease. In order to complete the case it is necessary to exclude all other possibilities of contamination of the shell-fish between the date of gathering from the mussel bed and that of sale and consumption in the town. It is well known that shell-fish are sometimes kept by the dealers for a considerable time before being sold, and the possibility of contamination from sources other than the natural habitat of the shell-fish must often be a very real one.

As the Conway mussels were getting a bad name in some markets, and as the industry was an important one locally and well worth attempting to save, the idea* occurred to us of trying to induce the fishermen to establish a practice of transplanting their mussels for a few days into cleaner water before sending them to market. So with the object of having more definite data on which to base recommendations, Mr. Johnstone made a series of experiments during 1908 to ascertain the conditions under which polluted Conway mussels would cleanse themselves from sewage bacteria when placed in unpolluted water in the Conway neighbourhood. A locality at the entrance to the estuary, on the Morfa beach, was selected because the water there was found, as the result of detailed bacteriological examination, to be much more pure than that of the Conway Estuary in general. Several lots of polluted mussels were then taken from the worst parts of the Conway beds and were placed in boxes fastened to the shore at the chosen part of Morfa beach. Samples of these mussels were examined bacteriologically at the beginning of the experiment, and further samples were examined 4, 8 and 16 days after

* The suggestion was also made by Dr. Klein in his Report to the Fishmongers' Company.

re-laying. The change after 4 days was most definite. In the mussels as laid down the average number of colon-like bacteria on each of the culture plates was about 200; while in the case of those that had been transplanted for 4 days the number in the similar cultures was about 40. In most cases the reduction showed a loss of 93 per cent. in the 4 days. In some cases the reduction amounted to a total disappearance of the "coli" organisms. It is clear then from these experiments made, not in the bacteriological laboratory, but in the open under natural conditions, that a very considerable degree of cleansing follows when badly polluted mussels are re-laid in unpolluted water, and that a period of four days is long enough for practical purposes. After the fourth day little or no further cleansing takes place.

The recommendation* was therefore made that mussels taken from certain specified grounds which were known to be badly polluted ought to be re-laid on the Morfa beach for at least 4 days before being sent to market. Compared with the capital value represented by the Conway mussel ground, and with the increased sales which would no doubt result from the confidence on the part of the purchaser that the mussels were free from danger, the initial and current expenses of this system of re-laying at Morfa would be quite trifling. It is surprising that the fishermen do not endeavour to make their industry more lucrative by themselves putting the recommendation into force.

The Corporation of Conway made an attempt last winter to compel the fishermen to reform the fishery.

* The results of the experimental work were reported to our Scientific Sub-Committee and were discussed in February, 1909, and again the following November; but it was found that the Sea Fisheries Committee had no power to establish such cleansing depôts, nor to make regulations enforcing their use if established.

Impelled by the decline of the fishery, by the condemnation of Public Health Authorities, and by our own adverse reports, they applied to the Board of Agriculture and Fisheries for an Order enabling them to improve, maintain and regulate the mussel fishery in the estuary, and a Public Enquiry was held at Conway in December by an Official of the Board. The object of the Order was to enable the Corporation to take such steps as might be necessary for the continuance and development of the fishery, consistent with the protection of the public health; and the provisions of the Order included the establishment of cleansing depôts such as had been recommended in Mr. Johnstone's Report.

At the Enquiry the fishermen took up an impossible position. They did not want the Order in any form, they objected to the regulations suggested, and especially to the proposed royalty of 6d. per cwt. to pay the expenses of the improvements. They denied that the mussels communicated disease, and asserted that there was more demand for them all over England and Wales and in Conway than there ever had been, and that they never had complaints. They expressed the belief that ruin would fall upon them and Conway if the Order became law. The only object of the Corporation, in promoting the Order, they said, was to get money. If it were confirmed "everybody would haul up their boats and tackle." In cross-examination they denied that they washed their mussels near the sewers—a practice which had been observed by both the late Dr. Bulstrode and Mr. Johnstone when making their inspections, on several occasions. This uncompromising hostility to regulation on the part of the men must do harm to the industry. The Conway mussels are regarded with suspicion, and it is probable that the fishery, in the absence of any regula-

tion, may still further decline; and in view of the increasing pollution of the estuary, it may become a dangerous source of epidemic disease.

As Mr. Johnstone has pointed out in his last report to our Committee, this is all very regrettable, for there is absolutely no doubt the fishery can be developed and that risk of the communication of disease can be largely if not entirely averted. All that is required for this desirable consummation is the co-operation of the fishermen with the Corporation, and the sympathetic and intelligent regulation of the industry. There are, in my opinion, no obstacles which will not yield to careful study of the local conditions. Details of the construction of cleansing ponds and storage of the mussels are not likely to offer lasting difficulties. The mussels gathered might be classed and the royalty charged in proportion to their quality. When a man placed his shell-fish in the cleansing ponds he might be given a receipt, on production of which he would receive the same quantity of cleansed mussels, of the same class, at the expiration of a given time. The shell-fish would be sent to the markets accompanied by a certificate, and public confidence in their harmlessness would again be restored.

In his Report to the Local Government Board the late Dr. Bulstrode saw no alternative, if this mussel industry were to continue, but to close the major portion of the Conway, and only to allow fishing on the seaward parts of the estuary "as a provisional measure." Either these measures are likely to be adopted by some Public Authority to be created by legislation, or the Conway mussels will gradually be excluded from the markets under the pressure of the Medical Officers of Health in the towns to which the mussels are consigned.

As an example of the situation likely to arise in

connection with many of our shell-fish beds, we may take the recent action of the Health Committee of Birmingham in refusing to admit mussels from a certain locality in Wales without a certificate of purity. As a result the fishermen have applied to our Committee to provide them with such a certificate. This is a matter requiring careful consideration. There is no doubt that such a certificate is wanted, and ought, under proper regulation, to be of great service in the interests both of the public health and of the fishing industries. But, if decided on, it must be granted not in relation to one locality only, but for each fishery of the District where the conditions are favourable, and could only be given after adequate inspection, and subject to periodic renewal. Unfortunately it could not be given for certain localities under their present conditions. Conditions, however, keep changing. Both shell-fish beds and sewage distribution undergo alteration, and so the pollution of a locality may improve or may become worse. Not only is each bed or laying a problem in itself, but it may be a different problem next year from what it is now. Moreover, in the case of beds that are condemned as dangerously polluted, remedial measures might well be undertaken. If compulsory cleansing of the living mussels in tanks of purer water for a short period before sending to market is not found efficacious, Dr. Bulstrode's suggestion of complete sterilisation by steaming, as is the custom with cockles at Leigh, may have to be adopted.

It is evident that if the shell-fish from specified localities in the District are or are not to be certified as fit for human food, some standard of permissible bacteriological impurity must be adopted. In respect of shell-fish examination as a matter of official routine, this

question now arises for the first time in this county. Hitherto no recognised standards have been established, since the kind of work done so far has consisted of investigation of the condition of shell-fish or shell-fish layings with reference to some special question—an epidemic, etc.—arising in relation to some specified locality. If the Committee should decide to issue certificates of purity—or withhold them—some standard of bacteriological impurity, as well as some standard of other available evidence, must be adopted.

It is fortunate that there are, in the Lancashire and Western Sea Fisheries District, some shell-fish areas which, so far as we can judge, are almost free from pollution—at least free from dangerous pollution. Bacteriological results obtained from such localities may assist in the formation of a standard. At all events it will be necessary for the Committee, in the absence of the guidance or the experience of other public bodies, to set up its own criteria of what constitutes a dangerously polluted mussel or cockle.

It is clear, then, that a very important part of the work of Sea Fisheries Authorities in the future, if our great shell-fish industries are to be maintained, will be the periodic inspection of the whole coast by competent scientific men working on rational lines, such as those adopted by the late Dr. Bulstrode, where all the factors of the problem are taken into consideration. The granting of a certificate implies the institution of some standard of purity and in fixing this topographical details must be fully considered; and the results of the further bacteriological analyses are to be interpreted in the light of such details. It is doubtful whether we are ever justified in applying the results of bacteriological analysis alone in administrative routine. It would, no

doubt, be very simple, and would seem desirable, if a Local Authority were able to reject or approve a consignment of shell-fish on the results of a routine examination in the bacteriological laboratory, and, if this were possible, much trouble would be avoided. Unfortunately, this simple procedure is not adequate, the trouble must be taken, common-sense topographical evidence must be considered or in many cases unjustifiable hardship would be inflicted on the fishermen, the industry would be seriously damaged, and the real source of pollution might fail to be traced. Over and over again in our local work we have come upon cases where either a favourable or an unfavourable bacteriological report in regard to a bed might have resulted according to the exact spot from which samples were gathered or the precise conditions under which they were taken. Moreover, in other cases we have shown that the bacteriological results can only be properly interpreted by those who have an intimate knowledge of the natural history of the locality.

All this kind of work, in the interests both of the public health and also of the fishermen who make their living from the shell-fish industries, ought to be undertaken in all cases by a biological Bacteriologist who is at the same time a good Field Naturalist and a Fisheries Expert.

In a rational bacteriology upon which regulation of an industry may come to be based, and from which conclusions as to the source and the history of the infection may have to be drawn, it is not sufficient merely to record the proportion of a certain sample of shell-fish in which a certain organism was observed. For example, the type of statement which one meets with in the annual reports of Medical Officers of Health, that

out of so many oysters or mussels examined during the year a certain number contained "coli" and a certain number "enteritidis," is useless for all practical purposes, and cannot lead to any result. As I have shown above, the significance of "coli" infection lies not in the mere presence but in the relative abundance of the organism. Records of the bacteriology of samples of shell-fish are futile unless one knows in detail where the shell-fish came from, the conditions under which they were collected, their history since the time of collecting and the relative number of each kind of organism present. The presence of such an organism as *B. coli* in relatively small quantity, and possibly of remote origin, may be of no importance in connection with the public health, and at most it merely indicates the possibility that the shell-fish in question may under certain circumstances contain pathogenic organisms. When the number of organisms present is relatively great, and when there is topographical evidence of comparatively recent contamination, then the risk of pathogenic organisms being present—whether actually isolated or not—is much greater, and condemnation of the shell-fish becomes justifiable. But unless the relative amount of infection is determined, and the various factors in the environment affecting the problem are known in detail, the laboratory bacteriologist or public health official runs some risk of being deceived by the samples examined and of arriving at erroneous conclusions, from routine analyses, as to the real condition and history of the suspected shell-fish in relation to sewage contamination.

In sea-fisheries investigation and administration we must be careful that bacteriology remains our useful servant and does not become a tyrannical master.

REPORT ON THE EXAMINATION OF THE
MUSSEL BEDS IN THE ESTUARY OF THE
WYRE WITH REFERENCE TO THEIR
LIABILITY TO CONTAMINATION BY
SEWAGE.

By JAMES JOHNSTONE, B.Sc.

Early in the present year (1911) Dr. Jenkins received a communication from the Medical Officer of Health of an inland town with reference to a consignment of mussels said to have been sent from the Estuary of the Wyre. A bacteriological examination of these shell-fish had been made, and it was stated that the analysis gave evidence of an undesirable degree of pollution by sewage bacteria. In consequence of this report Dr. Jenkins suggested to me that it would be desirable to make an inspection of the condition of the mussel beds in the Wyre area; all the more so since those shell-fish have not been examined since the former sewerage system of Fleetwood was replaced by that now in operation. I accordingly made three visits to the Wyre Estuary—on 9th February, 22nd February, and 9th March—and collected samples for examination on the two latter occasions. I also received a further sample of mussels on April 29th from Mr. John Wright, who collected the shell-fish according to instructions.

I have much pleasure in acknowledging the assistance and co-operation of Mr. T. R. Bailey, the Port Sanitary Inspector, who accompanied me and Mr. J. Wright on each of our visits of inspection. The sketch chart of the sewage outfalls reproduced here has been marked by Mr. Bailey from the Surveyor's plans.

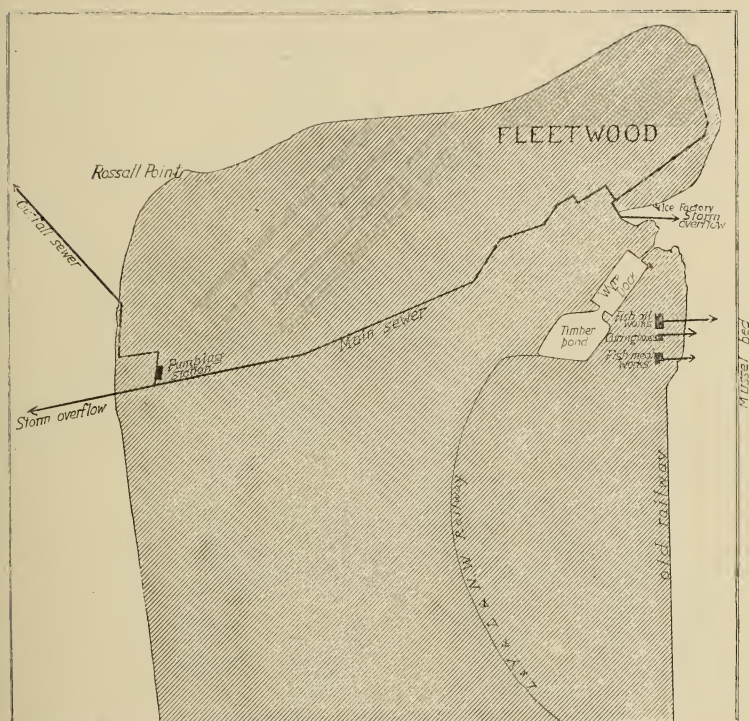
The Fleetwood Sewage Outfalls.

The whole of the Fleetwood sewage was formerly discharged into the Wyre at various points between the docks and ferry, through separate outfall sewers, and it is these that are shown on the chart published by the Royal Commission on Sewage Disposal. At the present time the untreated sewage of the Urban District (the population of which in 1909 was estimated at 15,000) is intercepted by a sewer which runs westwards towards the Rossall shore, and discharges through an 18-inch outfall sewer near Rossall Landmark. There is a storm overflow near the pumping station on the Rossall side, and another storm overflow discharges into Fleetwood Harbour. There are two very small sewers near the Knottend Ferry. The Wyre also receives the untreated sewage from Poulton-le-Fylde from an outfall discharging on the West side of the Estuary near Skippool Marsh; and a small sewer discharges on the East side, about half a mile above Wardley's Hotel near the brook called Peg's Pool.

In addition to these outfalls there are drains conveying effluents from (1) a fish oil works, (2) a fish curing house, and (3) a fish meal works, all of which factories are situated on the side of the Estuary near the docks. These drains are 6-inch pipes about 100 to about 300 yards long. They discharge on the beach well above the level of low water of ordinary tides, and the effluents reach the channel through little brooks, and flow right over the mussel beds, between Preesall and the docks. There is also a small drain from an ice factory, opening into the harbour.

It will be gathered from the foregoing description, and from the sketch chart, that the conditions in the Wyre Estuary, as regards liability of sewage contamina-

tion of the mussels and oysters bedded there, are fairly good. There can be no question of the Fleetwood sewage fouling the mussel beds in the Wyre: it is discharged on to the Rossall shore where there are no shell-fish beds—at least none that need concern us here; and if we may assume that the storm overflow in the harbour always serves the purpose for which it was designed, we may



dismiss the question of the sewage of Fleetwood itself. Two sources of pollution need only be considered, (1) the effluents from the works mentioned above, and (2) the sewage of Hambleton and Poulton-le-Fylde. It was the presence of these sources of pollution that made bacteriological analyses necessary.

Bacteriological Analyses.

- (1) Mussels from the beds near the docks (2 analyses).
- (2) Mussels from the beds at Wardley's.
- (3) Estuarine water from the channel near the docks.
- (4) Water from the channel adjacent to the Wardley's Ferry Slip.
- (5) Effluents from the fish oil and fish meal works.

Methods.

I give an outline of the methods of analysis; obviously the comparative value of such analyses depends on the methods employed. Grünbaum's neutral-red, bile-salt, lactose agar medium was employed for the isolation of the bacteria regarded as significant of faecal pollution.

Five mussels formed a sample. The soft parts were removed from the shells and cut up finely with scissors, then ground up in a mortar, and made up to a volume of 250 c.c. with sterile water. One c.c. of this emulsion, containing 1/50th part of a single mussel, was then plated in the agar medium mentioned; five such plates were made in each analysis.

One c.c. of the water was similarly plated.

In the case of the manufacturing effluents dilutions were made so that 1 c.c. of each corresponded to 0.1, 0.01, 0.001 of the original liquid. 1 c.c. of the original liquid, and 1 c.c. of each diluent, were plated as in the case of the water. In all cases the usual precautions to obtain sterility of the apparatus and materials used were taken; and control plates to test the sterility (to the agar medium employed) of the water used for dilution, the air of the laboratory, and the hands of the operator, were made. The results of the analyses were as follows:

- (1) Mussels from the beds near the docks.—
- (a) Taken at low water of a neap tide: The average

number of intestinal bacteria contained in one mussel was 65. (b) Taken at low water of a spring tide: The average number of intestinal bacteria contained in one mussel was 90.

(2) Mussels raked from the channel near Wardley's Ferry Slip: The average number of intestinal bacteria contained in one mussel was 150.

(3) Estuarine water from the channel adjacent to the place where samples (1) and (2) were taken: 1 c.c. of the water contained, on the average, 0.7 bacteria (less than one organism per 1 c.c.).

(4) Water from the channel adjacent to the Wardley's Ferry Slip: 1 c.c. contained, on the average, 22 intestinal bacteria.

Those unfamiliar with the bacteriology of shell-fish and sewage effluents may best appreciate the meaning of these results from the following comparisons. As a standard result which may enable us to assign a value to the Wyre analytical figures we may take the case of the Estuary of the Conway River in North Wales, where the sources of sewage contamination are abundant and obvious; and where there is actual epidemiological evidence of the transmission of enteric fever by the mussels taken from the estuary. Mussels taken from these beds contained, on the average, about 2,000 intestinal bacteria each, the analysis being made by methods identical with those described above.*

*Mussels bought from a retail shop may be very much worse than those taken from a badly polluted Estuarine area. In one sample bought from a low-class Liverpool fish-shop I found—as the average of ten mussels—that each shell-fish contained 17,150 intestinal bacteria. It must often be the case that multiplication of the contained bacteria—perhaps even direct re-infection—may take place during storage in insanitary premises; and obviously it would be unfair to lay the blame of such excessive pollution on the natural conditions of the beds from which the shell-fish were collected.

In this case the water of the Estuary contained, at the worst place sampled, 156 intestinal bacteria per c.c.; and, on the average, 35 per c.c.

Judged, then, by such standards the mussels taken from the Wyre near Fleetwood Docks, and from the channel at Wardley's, do not appear to be dangerously polluted; and the water in the lower reach of the estuary is also passably clean. Two matters, however, appear to require special consideration. These are:—

(1) *The pollution of the Estuary at Wardley's.*

It will be seen that the average number of intestinal bacteria contained in the surface water near the Wardley's Ferry is too high to be neglected. At this point the influence of the pollution from Poulton, and that of the outfall sewer at Peg's Pool, are felt. Nevertheless, the mussels taken from the bottom of the channel at Wardley's are very similar as regards contamination to those from further down the Estuary. The sample taken was practically fresh water, and the sewage probably floats on the surface and may not generally come in actual contact with the mussels on the bottom of the channel. The mussels on the foreshore near low water mark may, at times, give evidence of more serious pollution, but it does not appear that these are taken for immediate marketable purposes. The conditions at this part of the Estuary might be improved if the Poulton sewage were intercepted and discharged for a short time only at the beginning of ebb tide. It would then be greatly diluted and would not seriously affect the shell-fish at the bottom of the channel. So far as the results of these analyses go there does not appear to be much danger of pollution by the Poulton sewage, but nevertheless the relatively high bacterial

contents of the estuarine water at Wardley's does indicate the possibility of a fouling of the mussels under certain circumstances.

(2) *The Effluents from the Fish Refuse Works.*

Cultures were made from the effluent proceeding from the Fish Oil Works with the object of isolating any intestinal bacteria that might be contained therein. Plates inoculated with 1 c.c., 0.1 c.c. 0.01 c.c. and 0.001 c.c. were made, but all were sterile, *Bacillus coli* being certainly absent from these quantities of the effluent.

Similar quantities of the effluent from the Fish Meal Works were also analysed. Plates containing 0.1, 0.01 and 0.001 c.c. were sterile after 48 hours' incubation; but the plate containing 1 c.c. showed a small patch of colonies. This, however, was, I think, due to accidental contamination from a pipette used in inoculation.

Ordinary domestic sewage may be taken as containing from 10,000 to 1,000,000 *Bacillus coli* per c.c. The effluents in question are no worse than the estuarine water, and so far as this analysis goes they need not be regarded as contributing to the pollution of the mussels by intestinal bacteria.

These effluents are offensively smelling liquids. As discharged on the beach they were, when I saw them, clear, rather warm, and sometimes oily looking. The smell was not that of putrefying organic matter, but rather suggested aromatic compounds of some kind: phenol, however, was not present in appreciable quantity. Samples were placed in sterile flasks and incubated at ordinary room temperature, but the liquids did not contain any appreciable quantity of putrescible

substance, and the smell disappeared completely after two days. They were very slightly turbid, but no more so than ordinary river water.

In February, 1908, a sample of one of these effluents was sent to me for examination. It was highly septic, containing (in nutrient agar cultures) over 100,000 and less than 1,000,000 bacteria per c.c. It contained no antiseptic substances, and when dosed with sugar an abundant growth of bacteria and infusoria appeared. It had the same offensive smell possessed by the effluents examined this year. It was subjected to chemical analysis at the County Laboratories, and gave the following results:—

In parts per 100,000.

Total solid matter in solution...	...	1633·2
Oxygen required to oxidise in		
(1) 15 minutes ... ..	...	3·7
(2) 4 hours ... ..	...	11·8
Ammonia ... ..	...	12·5
Ammonia (from organic matter by distillation with alkaline permanganate)		5·4
Sulphuretted hydrogen ... ..	...	0·36

Mixed with tap water (10 per cent. effluent and 90 per cent. water) and allowed to stand three hours, the mixture lost five-sixths of its total dissolved oxygen; and allowed to stand twenty hours it lost twelve-thirteenths of its dissolved oxygen. The Analyst reported that “Fish would be suffocated for want of air in such a mixture of effluent and water, or even with a smaller proportion of effluent.”

I did not collect this sample myself, and am therefore unable to say whether or not the effluent may have been accidentally contaminated by bacteria during collection.

It does not appear probable that there is any danger of the pollution of the mussels by human or animal faecal matter by means of these effluents, and this is the danger with which we are more immediately concerned. But some attention should be directed to the pollution of the foreshore and shell-fish by a discharge which appears to be a noxious one, and which the Committee may be empowered to prevent. Whether or not the emanations from the Fish Oil and Fish Meal Works constitute a technical "nuisance" is a matter for consideration by the local sanitary authority; but the fouling of the foreshore and shell-fish by an undoubted manufacturing effluent (not a sewage effluent) is a matter that comes within the purview of the local fisheries authority. I would direct attention to the recently published report on the shell-fish beds of England and Wales by the late Dr. Bulstrode, of the Local Government Board, in which this particular case of pollution is considered.*

The effluents in question are described as offensive ones, and it is stated that the poor quality of the mussels on the foreshore is due to the detrimental effect of the effluents. In the Analyst's Report quoted above, the opinion is expressed that the liquids would be harmful to fish life because they would deprive the estuarine water of a large part of its contained oxygen. It is true that, as a rule, the discharge would be greatly diluted, still it would probably happen repeatedly that small parts of the mussel bed on the foreshore would be bathed in effluent which had undergone little dilution—even dilution to the extent of 90 per cent. would be likely to be prejudicial according to the chemical analysis—and

* Supplement to Rept. Med. Off. Loc. Govt. Bd. for 1909-10—Shell-fish other than oysters in relation to disease. By H. T. Bulstrode, M.D., p. 222; [Cd. 5313] 1911.

to that extent the discharge would be noxious to the fisheries.

I do not know what is the precise nature of the manufacturing process at either of the works mentioned; or whether the effluents are always of approximately the same nature. Obviously further examination, from the point of view of the fisheries, is desirable.

AN INTENSIVE STUDY OF THE MARINE PLANKTON AROUND THE SOUTH END OF THE ISLE OF MAN.—PART V.

By W. A. HERDMAN, F.R.S., and ANDREW SCOTT, A.L.S.

METHODS.

The work was carried on during 1911 on the same lines as in previous years. Mr. W. Riddell again gave most efficient help at sea, in the observations taken from the yacht; Mr. Chadwick and Mr. T. N. Cregeen, of the Port Erin Biological Station, collected the samples from Port Erin Bay throughout the year; the two authors divided the rest of the work as before; and Miss H. M. Lewis, in the Zoological Department of the University of Liverpool, devoted a great deal of time and trouble to compiling the statistics, tables, curves and diagrams from which this paper is written.

The work at sea from the steam-yacht "Runa" was carried on for some weeks in April, and again in the later summer (August and September), usually the two most important times of planktonic change. During the rest of the year, statistical weekly gatherings were taken for us in Port Erin Bay, in accordance with a uniform plan, by the staff of the Biological Station.

We do not propose this year to make such a detailed statement of the results as we have done for previous years, but rather to give conclusions and comparisons, and to pick out for remark any matters that seem new or unusual. Consequently we would refer readers who are interested in a fuller discussion of any points we have already dealt with to the preceding four parts of this work. (See Reports for 1907-1910.)

MATERIAL AVAILABLE.

The collections made this year have amounted to over 500—within the limited area off the Isle of Man to which this “Intensive Study” applies. This series compares with those of former years, as follows:—

Year.	At Sea, from Yacht.		In Bay throughout Year.	Totals.
	Spring.	Autumn.		
1907	218	279	138	635
1908	156	242	157	555
1909	329	147	231 + 49	756
1910	107	249	296	652
1911	120	84	314	518
Totals ...	930	1,001	1,185	3,116

These make about 1000 in each of the three vertical columns—Spring, Autumn and Bay—and from over 500 to over 750 for each of the five years in question.

The remarks made in the previous Reports about the nets used and the methods adopted apply again; but for the vertical hauls we have used almost wholly the Nansen net, either open throughout the haul or closed after traversing a certain zone. The other nets used were “coarse” and “fine” (No. 20 silk) horizontal, “funnel” net, “Otter” net, “medium Nansen,” “large Nansen,” and “Shear” net. All these nets and the methods in which we use them have been sufficiently described in the previous parts of this study.

PLANKTON OF PORT ERIN BAY IN 1911.

The plan adopted for the last few years in regard to the plankton samples from Port Erin Bay has been to take two horizontal (coarse and fine nets) and one vertical haul twice each week throughout the year—thus giving

six samples in the week. The twelve months in 1911 are represented as follows:—

Months ...	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Gatherings	27	18	30	31	27	31	27	23	27	22	24	27

Each month is thus represented by a considerable amount of material, the average per month being about 26 hauls. The lowest monthly records are 18 for February and 22 for October, and the highest, 31 for April and June. It has to be added that in April, August and September additional material, obtained from the "Runa" outside the bay, is also available for comparison.

Treating these records in the same way as in previous years and comparing the results we find that:—

- (1) The monthly averages for the horizontal nets are not quite so large as those of last year. In 1910 the highest was 63 c.c; in 1911 it was 46 c.c.
- (2) The maximum was reached a month later—in May in place of April. If we analyse this maximum into its three most important constituents, we find that in 1911:—

The Diatom maximum was in May.

The Dinoflagellate maximum was in June.

The Copepod maximum was in July.

The vertical hauls at the mouth of the Bay, as on previous occasions, agreed well in their evidence with the much larger bulk of material obtained from the horizontal nets. The maxima in the vertical hauls were at the times stated above and the quantities were:—

In 1910 (April and May) about 4 c.c. per haul.

In 1911 (May and June) about 5 c.c. per haul.

It may be noted here that in 1911 the hours of sunshine reached the monthly maximum in May, and the total number was considerably greater than that of 1910. (See below under Sunshine.)

If now we neglect the vertical hauls—which are not directly comparable with the horizontal—and treat each pair of coarse and fine net samples taken at the same time as forming together a single double haul, we get the following result for the twelve months:—

1911.	Double hauls.	Average catch.	Diatoms.	Dinoflagellates.	Copepoda.	Copepod juv.	Copepod nauplii.
January	9	3·6	52,064	3,511	3,314	188	1,553
February ...	6	4·0	60,528	2,508	2,579	222	2,537
March	10	4·4	245,851	2,495	1,013	175	3,062
April	11	9·0	240,446	901	2,752	246	3,520
May	9	46·0	24,201,900	26,230	9,187	2,039	15,240
June	11	37·3	3,767,835	50,365	25,285	1,762	44,820
July	9	18·8	8,209	18,967	75,533	1,229	62,618
August	8	11·4	1,998	1,510	61,351	2,426	35,058
September ...	9	15·3	928,501	8,818	31,651	2,426	44,244
October	8	14·5	4,742,791	10,510	18,559	1,700	32,058
November ...	8	5·5	506,729	6,574	20,741	894	8,058
December ...	9	3·4	124,144	5,131	10,492	124	5,190

This table serves for comparison with those we have published for 1909 in Part III, p. 212, and for 1910 in Part IV, p. 199; and shows very clearly the average monthly catches, forming a simple curve rising steadily from 3·6 c.c. in January to 46 c.c. in May, and then declining to 3·4 c.c. in December. It also shows the two maxima in the Diatom column, the first in May with over 24 millions and the second in October with nearly 5 millions. Finally the succession of maxima, Diatoms in May, Dinoflagellates in June, and Copepods in July, is clearly seen. These maxima are all large ones, in the case of Diatoms and Copepoda much larger than in the previous two years, and in the case of the Dinoflagellates only exceeded by that of 1910.

If we add together Diatoms and Dinoflagellates in

May and June (the months when phytoplankton predominates), and compare the total with that for Copepoda (both young and adult) in July and August (months of the zooplankton maximum) the contrast is obvious.

	Phytoplankton.	Zooplankton.
May + June	28,046,330	98,333
July + August	30,684	238,215

These are, moreover, not the largest hauls in any of the cases, but only monthly averages; and in the right-hand column it is only the Copepod zooplankton that is taken into account. Still the differences are quite sufficient to show the changes in the nature of the predominant plankton in passing from the one period to the other.

It is always necessary to analyse the total numbers for the days, or nets, whenever a sudden change is seen, in order to determine what has caused the change. For example, in 1911, on April 21st the total catch in the coarse net went up to 22·5 c.c. from an average of about 4·0 c.c. during the previous gatherings of the same net that month. The gathering immediately before, on April 18th, was 4·5 c.c. Now this great increase in bulk—about five-fold—was not due to any increase in numbers in any one of the more important groups, as the following figures will show:—

		Diatoms.	Dinoflagellates.	Copepoda.	Copepod nauplii.
April 18	4·5 c.c.	238,000	3,000	7,651	7,000
April 21	22·5 c.c.	194,000	0	2,403	4,800

It is evident that these figures for Diatoms, Copepoda, etc., do not account for the rise in volume of April 21st.

It is necessary, then, to examine the specific details, when we find that an increase in the number of Medusae, polychaet larvae, fish eggs, and a few other larger

organisms occurred on the 21st, and caused the increase in the volume of the catch although not in the number of organisms caught.

In the case, on the other hand, of a sudden rise early the following month from 7 c.c. on May 4th to 20·5 c.c. on May 10th, the number of Diatoms rose from 115,450 to 2,268,750, which quite accounts for the increase in volume of the catch, and this was in fact the beginning of the vernal Diatom maximum, and the numbers of c.c. went on in the next few days to 35·7, 42·8, etc., all caused by Diatoms in tens of millions. As an example of how thick the water was with phytoplankton at the time, it may be stated that on May 16th, when the largest horizontal hauls were obtained (42·8 in coarse, and 60·2 in the fine net), the vertical net hauled through only six fathoms gave 17·2 c.c. (a very large haul for the vertical net) and contained nearly three millions of Diatoms. As a contrast to that, we have a month later the vertical net, on June 15th, giving 16 c.c. (nearly the same volume of catch) with only 8,200 Diatoms. On looking into the specific details the cause is seen to be the great increase in the number of Copepoda on the latter date.

BAY DIATOMS.

The following notes as to the occurrence of the Diatoms at Port Erin at the time of the vernal maximum were taken at the time of collecting, but have been revised and added to since as a result of examining the catches in detail:—

May 13th.—The Vernal Diatoms now appeared in quantities (calm weather with a marked rise in temperature).

May 16th.—Tow-net gatherings large, and consisted almost entirely of Diatoms (weather continues

calm and the increase in temperature is maintained).

May 19th.—Diatoms occurred in very large quantities, especially in the fine net.

May 22nd.—Catches rather smaller, but Diatoms still in abundance, even in the vertical net (weather still fine and warm).

May 25th.—Diatoms much less numerous. Fine net had only about one-tenth, or less, of the gatherings on May 19th (no obvious change in weather conditions).

All the above large catches of Diatoms consisted almost entirely of species of *Chaetoceras*. It was not until a week later that *Rhizosolenia* (chiefly *R. semispina*) made its appearance. It reached its maximum early in June, and then gradually died off. By the beginning of July the Diatoms had practically disappeared.

The following gives the quantity of plankton and the total number of Diatoms present in each haul of the fine net taken during the month of the Diatom maximum:—

	Date.	Quantity in c.c.	Total Diatoms.
May	1.....	2.5	43,360
„	4.....	1.0	10,610
„	10.....	6.5	525,680
„	13.....	30.2	19,118,000
„	16.....	60.2	54,141,500
„	19.....	54.5	34,447,500
„	22.....	30.5	27,775,000
„	25.....	8.3	2,504,500
„	29.....	14.8	22,023,100
June	1.....	11.3	4,926,000
„	3.....	24.7	12,943,000
„	5.....	12.7	2,656,000

The sudden rise on June 3rd is due to *Rhizosolenia semispina*. The figures given above for May are unusually large, and the increase from about ten thousand on May 4th to over fifty-four millions on May

16th is most rapid. The most abundant species were *Chaetoceras debile* and *Ch. sociale*. On May 16th the first of these species reached 30,000,000, and the second 12,000,000 per haul.

THE MORE IMPORTANT GENERA OF DIATOMS.

We have taken out again the same seven genera as in our last report, viz., *Biddulphia*, *Chaetoceras*, *Coscinodiscus*, *Rhizosolenia*, *Thalassiosira*, *Guinardia* and *Lauderia*.

We think it unnecessary to print the detailed tables again this year. Those we gave last year (Part IV, pp. 204-6) form a very good example, and we shall merely note here the points in which the details for each of the seven genera differ in 1911 from those recorded for 1910.

Biddulphia.—Does not attain to quite such high numbers in spring this year, and the highest record (312,560) is in April in place of March; but after dying out completely in summer, the genus has a second, and this year a greater, maximum in November (660,600 on November 24th), when there is the high monthly average of 341,231—last year it was under 40,000.

Chaetoceras.—Last year the maximum of this genus (49 millions) was in April. This year it is a month later with 68 millions on May 16th. The autumnal, smaller maximum is larger than in the previous year, and reaches over 10 millions on October 2nd, and about 6 millions on October 16th and 19th.

Coscinodiscus.—The spring maximum was earlier this year than in 1910, and reached 392,400 on March 14th. An unusually late haul was 79,290 on May 1st. The autumn increase was unusually great, the maxima being 42,400 on October 10th, 44,700 on October 16th,

and 40,450 on November 27th, as against 11,400, the highest number in these months in 1910.

Rhizosolenia.—This important genus again had its maximum in June, but did not reach so high a point as in 1910. Notable hauls are 2,160,000 on May 22nd, 2,880,000 on May 29th, four hauls of from $3\frac{1}{2}$ to over 10 millions between June 3rd and 8th. The autumnal increase this year did not amount to much, the largest haul being 276,000 on October 19th.

Thalassiosira.—The spring maximum was again in May, with 1,120,000 on May 29th. Quantities of several hundred thousand per haul remained until June 5th, and then the genus suddenly disappeared and was unrepresented until October 5th, when 287,000 were taken in one haul.

Guinardia.—This genus is very poorly represented this year, the highest figure being 204,000 on June 1st, compared with nearly nine millions the previous year.

Lauderia.—This form also shows smaller numbers than in 1910. The only haul of over a million was 1,203,500 on May 19th—whereas it attained to 20 millions in April, 1910.

We add here the monthly averages of these seven genera of Diatoms, as follows:—

1911.	Biddul- phia.	Chaeto- ceras.	Coscino- discus.	Rhizoso- lenia.	Thalassi- osira.	Guinardia.	Lauderia.
Jan.	31,758	11,903	5,119	64	0	22	0
Feb.	38,150	8,606	11,572	50	0	133	33
March.....	124,225	41,990	73,796	1,425	0	283	160
April	115,823	86,185	34,890	1,650	0	82	150
May	21,139	22,745,683	17,531	858,208	217,329	27,938	312,363
June	2,073	1,431,005	200	2,121,226	135,073	60,656	12,864
July	0	478	0	7,180	0	551	0
August ...	219	1,437	12	310	0	31	0
Sept.	11,110	868,017	1,479	21,018	0	481	1,511
Oct.	142,690	3,956,047	25,444	72,622	84,462	987	41,387
Nov.	341,231	143,251	17,402	0	12	2,597	12
Dec.	77,788	31,159	9,411	0	0	4	0

The above table brings out clearly the marked Diatom maximum in May, the minimum in July and August when very few Diatoms were present, and the second or autumnal maximum in October. The vernal and autumnal maxima are shown unusually clearly by *Thalassiosira*, which was present only at these periods, being totally absent from November to the end of April, and in July, August and September. Placed in the order of their highest monthly averages throughout the year, these common Diatoms are as follows:—

March—*Coscinodiscus*.

May—*Chaetoceras*, *Thalassiosira* and *Lauderia*.

June—*Rhizosolenia* and *Guinardia*.

November—*Biddulphia*.

On the whole, the regularity of occurrence and of waxing and waning throughout the year, rather than differences from year to year, is what strikes the observer as of primary importance.

Biddulphia mobiliensis and *B. sinensis*.

Both the species of *Biddulphia* which we have been obtaining in quantity during recent years (*B. mobiliensis* and *B. sinensis*) occurred in October this year, and even occasionally in September, an unusually early appearance for *B. sinensis*. Fig. 1 shows a typical example of a plankton containing abundance of both species, the longer and relatively narrower forms in the figure being *B. sinensis*, and the shorter, nearly square forms, *B. mobiliensis*: there are, of course, other differences which are not seen clearly in that figure. In the more enlarged micro-photograph (fig. 2), *a* points to a typical *B. mobiliensis* as seen in our district, and *b* to an



FIG. 1.



FIG. 2.

example of *B. sinensis*. Our *B. mobiliensis* undoubtedly approaches the form "*regia*," regarded as a distinct though allied species by Ostenfeld (Medd. Kom. Havunders., Plankton, Bd. I. 6, 1908). Gran, in the Diatomacea of the Nordisches Plankton, unites these two forms as *B. mobiliensis*.

In our district *B. sinensis* is of more elongated form than is shown in Ostenfeld's figures. Most of our specimens of *B. sinensis* are very distinct and easily distinguishable from the *mobiliensis-regia* group by the shape and the position of the spines, but we have found one or two specimens during this last year where one end of the cell bore the characters of *sinensis*, while the other had the appearance of *mobiliensis*. Until, however, we get further specimens we do not propose to base any opinion as to the species upon this possibly abnormal form. We are watching the fresh material of *B. sinensis* carefully in the present year (1912), and may return to the subject in our next report.

DINOFLAGELLATA.

The monthly averages for *Ceratium* and *Peridinium* throughout 1911 were as follows:—

1911.	<i>Ceratium</i> tripos.	<i>Peridinium</i> spp.	1911.	<i>Ceratium</i> tripos.	<i>Peridinium</i> spp.
January ...	3,402	44	July	17,942	864
February ...	1,815	0	August	1,385	125
March	1,820	0	September	8,478	33
April	505	2	October ...	8,422	12
May	9,131	6,522	November...	6,382	47
June	28,811	14,335	December ...	4,866	11

We have taken, in the case of *Ceratium*, the familiar form commonly known as *C. tripos*, without discriminating between the sub-species or varieties which

have been described. The other common species, *C. fusus* and *C. furca*, are also present, although they are not so abundant as *C. tripos*.

Under *Peridinium*, in these reports in the past, we have united several different forms, and we do so again in the table above and the one that follows to preserve continuity; but we shall give a further statement below as to the sub-genera and species of *Peridinium* that occur in our material.

Looking at the figures from which the table of monthly averages has been compiled, we find that the numbers in the case of both *Ceratium* and *Peridinium* begin to get larger towards the end of May, and reach their highest in June and early July. At that time of year (end of May and June), also, we find that all the common species are represented in all the nets used, as the following record of two adjacent hauls demonstrates:

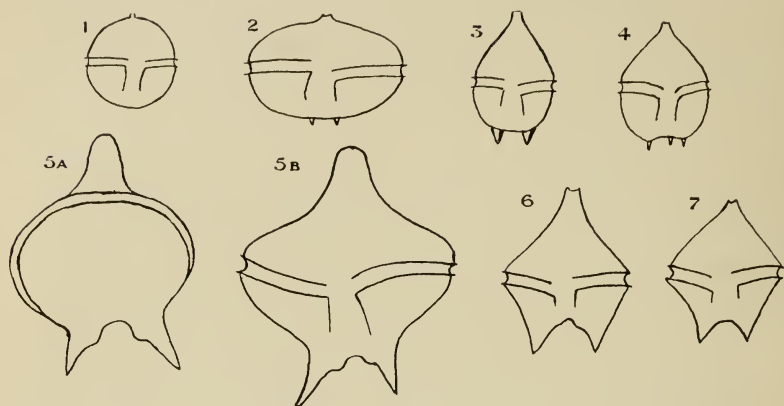
	May 29.			June 1st.		
	Coarse.	Fine.	Vertical.	Coarse.	Fine.	Vertical.
Species recorded.						
<i>Ceratium furca</i>	300	9,100	200	3,200	10,000	2,000
„ <i>fuscus</i>	100	1,000	50	1,000	2,000	1,500
„ <i>tripos</i>	4,500	3,500	150	8,800	10,000	2,000
<i>Peridinium</i> spp. ...	6,600	10,000	250	10,000	20,000	2,500

Although the above are representative hauls, they are none of them very large ones. We add the following records of greater numbers of *C. tripos* taken in single hauls:—

June	19th,	fine net	.....	30,000
„	30th,	„	.....	30,000
„	30th,	coarse net	.....	36,400
July	15th,	„	.....	76,600
Sept.	8th,	„	.....	57,000

Irish Sea Species of *Peridinium*.

Mr. Riddell has drawn up for us the following list, with diagnoses, of the species of *Peridinium* we have found, so far, in our district.



G. 3.

Genus PERIDINIUM.—Testa divided into plates; precingular plates seven, bottom plates two.

Sub-genus I.—PROTOPERIDINIUM: Girdle nearer apex on right side; usually no antapical horns; spines may be present.

- (1) *P. orbiculare*, Paulsen; globular, small; no spines and no apical horn; girdle almost equatorial. L. 0·04–0·045 mm. Rare in Irish Sea. (See fig. 3, No. 1.)
- (2) *P. ovatum*, Pouchet; depressed; apical horn not prominent; two antapical spines. L. 0·062 mm., greatest breadth 0·084 mm. Not uncommon. (Fig. 3, No. 2.)
- (3) *P. steini*, Jörg.; pyriform; apical horn distinct; two antapical spines, each winged. L. 0·045–0·052 mm. Rare. (Fig. 3, No. 3.)

- (4) *P. pellucidum*, Bergh; pyriform; girdle at right angles to long axis; three antapical spines. L. 0·045—0·068 mm. Rare. (Fig. 3, No. 4.)

Sub-genus II.—EUPERIDINIUM: Girdle nearer apex on left side; antapical horns often present.

- (1) *P. depressum*, Bailey; girdle oblique to long axis; horns subequal, hollow. L. 0·152—0·2 mm. Commonest form in Irish Sea. (Fig. 3, No. 5, A and B.)
- (2) *P. divergens*, Ehrenberg; girdle at right angles to long axis; inner side of antapical horns with protuberances. L. 0·08—0·084 mm. Rare. (Fig. 3, No. 6.)
- (3) *P. conicum*, Gran; girdle at right angles to long axis; antapical horns short and without protuberances; left border of longitudinal furrow straight. L. 0·048—0·06 mm. Rare. (Fig. 3, No. 7.)

NOCTILUCA.

The distribution of *Noctiluca* throughout the year, in 1911, was unusual in two respects—(1) in its presence in fair quantity during many months (ten), and (2) in having no marked maximum in summer and autumn. It seems to have remained in Port Erin Bay over the winter, and was caught during the early months of the year in diminishing numbers—up to 1,200 per haul in January, 300 in February, and 100 in March. It is not recorded in April and May, but re-appears in small numbers in June, reaches 1,200 in the best haul in July, a few in August, and 1,800 in September, 2,000 (the top figure) in October, fewer in November, and 1,600 in December.

Hauls of between one and two thousand occur at such diverse times of year as January, July, September, October and December.

COPEPODA.

On taking out again the records of occurrence of the nine commonest species of Copepoda, we get the following results:—

Calanus helgolandicus.—As usual, *Calanus* was present in small numbers throughout the year, but became much more abundant in summer, June to October, and especially in July, when two of the customary large swarms appeared—one on July 4th and the other on July 18th. The numbers, however, were throughout smaller than in 1910.

Pseudocalanus elongatus.—This is one of the most abundant species, and is present in quantity at Port Erin all the year round. The numbers begin to get progressively larger in April, May and June, to a maximum in July, after which they decrease irregularly through August and September. The greatest haul (54,350 on July 31st) is more than twice as large as the top haul of 1910.

Oithona similis.—The commonest Copepod in Port Erin Bay throughout the year is again *Oithona similis*. The greatest haul is 225,450 on July 18th, a very large number for a Copepod, in our standard hauls, and nearly twice as much as the largest (126,700 at Station I on August 20th) of the previous year. In general, the record is the same as before.

Temora longicornis.—This is a summer form, and this year it was only abundant in June and July. It has a remarkably symmetrical distribution, forming a simple normal curve, rising from an average of 1 per haul in January, having the maximum in summer, and sinking to 2 per haul in December. The average for June is 4,675 per haul and for July 4,706, and the two largest

hauls are 20,000 on June 3rd, and 17,900 on July 4th. *Temora*, with the same distribution throughout the year, was more abundant in 1910 and had its maximum at the end of July.

Paracalanus parvus.—Last year's remarks in regard to this species apply again. The maximum is again in September, and the largest hauls are 61,930 on August 24th, and 32,390 on September 29th.

Acartia clausi.—This species again only reaches high numbers in summer, and this year has its maximum in August—the only really large hauls were 59,360 on August 24th and 42,380 on October 19th.

Anomalocera patersoni.—This oceanic form was exceptionally rare at Port Erin in 1911, and was absent during most months of the year. A few stray individuals were present in June and July.

Centropages hamatus.—This is a summer form appearing in April, becoming more abundant in May, with a low maximum in June, and then dwindling gradually to September.

Microcalanus pusillus.—Last year's record again holds good for this species. The maximum in 1911 is in December, and the minimum in July, August and September.

Amongst other rarer Copepoda, *Euterpina acutifrons* is a winter form which occurred in fair quantity in November, December and January, and in no other month. *Isias clavipes* occurred in May, June, August, September and October, the two largest hauls being 130 on May 13th, and 156 on September 13th.

Omitting these latter, rarer, species, the monthly average hauls in Port Erin Bay for the above nine, more important, species of Copepoda are as follows:—

1911	Calanus.	Pseudocalanus.	Temora.	Centropages.	Anomalocera.	Acartia.	Oithona.	Paracalanus.	Microcalanus.
Jan. ...	4	370	1	0	0	60	2,589	99	14
Feb. ...	8	460	0	0	0	17	1,993	61	38
Mar. ...	1	476	63	0	0	17	428	23	5
April ...	4	1,554	305	7	0	197	675	7	13
May ...	15	1,501	282	42	0	1,627	5,647	39	11
June ...	85	4,168	4,675	81	1	4,858	11,745	326	32
July ...	339	12,012	4,706	45	1	5,376	52,393	667	0
Aug. ...	32	8,916	435	34	0	14,049	20,755	13,372	0
Sept. ...	68	4,129	69	28	0	4,234	9,000	14,100	0
Oct. ...	60	2,332	27	1	0	6,181	5,024	5,170	12
Nov. ...	3	3,056	3	0	0	222	11,912	5,506	31
Dec. ...	4	1,184	2	0	0	51	6,587	1,860	89

It must be remembered that the above figures are only the monthly averages, per haul, and that many of the individual hauls in each month were much larger, as we shall show below. *Anomalocera*, as it appears in the above table, would not be worthy of record were it not that it has assumed more importance in other years, and may do so again, and consequently it is well to preserve this year's record for comparison.

If we arrange the six most abundant of these species of Copepoda in the order of their abundance with their total numbers—and add the totals for the two previous years—they are as follows:—

	1911.	1910.	1909.
<i>Oithona similis</i>	1,155,108	872,678	465,066
<i>Pseudocalanus elongatus</i>	365,983	368,326	309,973
<i>Paracalanus parvus</i>	351,088	217,633	54,120
<i>Acartia clausi</i>	323,633	340,631	63,373
<i>Temora longicornis</i>	106,359	147,043	62,659
<i>Calanus helgolandicus</i>	5,843	15,481	21,412

This list shows that the only difference in the order is that this year *Paracalanus parvus* comes above *Acartia clausi*, while it was below in 1910 and 1909. The

progressive increase in the numbers of *Oithona similis* during the three years is noteworthy.

The greatest single hauls of Copepoda (taken with the ordinary "coarse" net) in Port Erin Bay, during 1911, were as follows:—

Species.	Number.	Date.
<i>Oithona similis</i>	214,000	July 18
	73,200	" 21
	68,000	Aug. 3
	51,300	" 24
<i>Pseudocalanus elongatus</i>	46,500	July 31
	34,350	Aug. 24
<i>Paracalanus parvus</i>	61,300	" 24
	32,300	Sept. 29
<i>Acartia clausi</i>	59,000	Aug. 24
	42,100	Oct. 19
<i>Temora longicornis</i>	17,000	June 3
	17,000	July 4
<i>Calanus helgolandicus</i>	1,800	" 18

Some of these are very large hauls indeed for Copepoda.

If we arrange all the species of Copepoda (15) recorded on our forms in 1911 in two series, according as they are supposed to be "Oceanic" or "Neritic," we get the following result:—

OCEANIC.

Calanus helgolandicus.
Pseudocalanus elongatus.
Oithona similis.
Paracalanus parvus.
 [Acartia clausi]
Anomalocera patersoni.
Microcalanus pusillus.
Metridia lucens.
Candacia armata.

NERITIC.

Temora longicornis.
 [Centropages hamatus]
Euterpina acutifrons.
Isias clavipes.
Parapontella brevicornis.
Labidocera wollastoni.

A few of these are undoubtedly oceanic and neritic respectively, for example *Calanus helgolandicus* is typically oceanic, while *Isias clavipes* is a shore form; but other cases are more doubtful. One would expect an oceanic form which only invades a shore area on occasions to have a more or less periodic distribution, but

Pseudocalanus elongatus and *Oithona similis*, usually regarded as oceanic, are present in quantity in Port Erin Bay all the year round. Again *Temora longicornis*, a reputed neritic species, is at Port Erin a summer form only abundant in June and July—a distribution which might be supposed to be characteristic of the immigration of an oceanic species. It must be remembered, however, that periodicity, and absence or great reduction in numbers during part of the year may be due to the normal life-history of a neritic species *in situ* and need not indicate invasion from outside.

The fresh evidence this year tends merely to confirm us in the opinion expressed in last year's report*, to the effect that—"It is improbable that all planktonic species are either oceanic or neritic. It may well be that some species are intermediate in character and habitat, overlapping and intermingling with both, and liable to be placed sometimes in the one category and sometimes in the other. Then again, there may be some species which are cosmopolitan, or 'Panthalassic,' as we should prefer to call it, occurring both in the open oceans and also in the shallower coastal waters of some parts of the world."

CLADOCERA.

This summer group ranged in 1911 from March 2nd to September 29th. *Podon* (with 3,500), and *Evadne* (with 6,460), both reached their highest point early in September; but *Podon* also showed large hauls in June (1,320) and August (1,350), and *Evadne* in June (6,000), July (2,400), and August (2,550). These numbers, it will be noticed, are distinctly larger than those for 1910.

* Lancashire Sea Fisheries Laboratory Report for 1910, p. 107.

SAGITTA.

This "Panthalassic" species (*S. bipunctata*), usually considered to be an oceanic form, was again present in Port Erin Bay in every month, with the maximum in summer (June), and a secondary increase in late autumn (November). It became more abundant in November after stormy weather had set in.

The monthly average hauls are as follows:—

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
9	22	7	7	66	244	64	30	15	28	59	9

The largest hauls are 206 on May 29th, 620 on June 1st, 1,300 on June 3rd, 250 on June 15th, and 412 on November 24th.

A haul of the shear-net five miles off land, at about 10 fathoms, on April 14th, gave 301 large specimens of *Sagitta*, although the surface nets worked at the same time caught none, and the medium Nansen hauled vertically from 20 fathoms showed only 4. This result suggests that at that time although not present at the surface *Sagitta* was abundant a few fathoms below.

OIKOPLEURA.

This form (*O. dioica*) has again the same sort of distribution curve throughout the year. It is present in every month, but the monthly average hauls only run to thousands from May to October, inclusive. The largest hauls are over 34,000 on May 1st, and over 15,000 on October 19th.

VARIOUS LARVAE.

Cirripede nauplii and other larval forms do not show anything very striking in their distribution this year, and so do not call for individual treatment. It will

suffice to put on record a few of the more exceptional hauls. Nearly 130,000 young Polychaet larvae were taken in Port Erin Bay on February 17th, and over 33,000 on March 11th, 8,000 Lamellibranch fry on May 4th, 11,000 Gastropod larvae on July 18th, over 2,000 Echinoderm larvae on August 7th, over 5,000 on September 4th, and 4,700 on September 11th, over 4,000 young Medusae on September 4th, and over 5,000 "Mitraria" on December 26th. In the later part of the year the following large hauls of Lamellibranch larvae were taken: 35,000 on September 25th, 17,000 on October 2nd, 19,000 on October 27th, 15,000 on November 1st, 11,000 on November 10th, and 22,000 on December 26th. It is probable that the large scallop bed (*Pecten opercularis*) lying outside Port Erin Bay to the North accounts for many of the young Lamellibranch fry that are so abundant from time to time.

FISH EGGS.

Rockling eggs continue to be abundant, and have an extraordinarily wide range through the year, as they are only absent in October and November. The maximum is in March, with an average of 49 per haul. The eggs of one of the species of Rockling occurred in a sample of Plankton collected on December 29th, which is unusually early, as these eggs are not often found in our seas before the end of January. The "mackerel midge" (a little narrow silvery fish about an inch long), which is a young stage of one of the Rocklings, is of economic importance as it sometimes forms a considerable part of the food of the Mackerel visiting the Irish Sea in summer. The young Rockling live near the surface and are frequently taken in the tow-net between June and August.

The other fish eggs range from January to August inclusive, with a maximum of about 20 per haul in the bay during March and April. Out at sea during April the average per haul is about 36, the largest hauls being 62 per net on April 10th and 63 per net on April 27th.

A haul of the large Nansen net on April 12th secured 1,059 fish eggs, and 2,470 on April 24th. Both these hauls were outside the bay, and the eggs caught were as follows:—

	April 12	April 24
Rockling	750	650
Bib	25	300
Whiting	230	1,500
Dab	50	0
Sail-fluke	0	20
Plaice	4	0

COMPARISON OF NETS AND CATCHES.

There is little, if anything, to add as to the catching power of the different nets to what we have written in the previous parts of this report. It may just be worth noting that:—

In our experimental hauls from the yacht the coarse net consistently caught from twice to ten times as much as the fine, both in spring and autumn.

The two nets fitted with Otter boards and towed well forward in the ship, so as not to be affected by the propeller, agreed fairly well in their results with one another, and with the fine net at the stern. There is nothing to add under this head to what we have already said.

With the small (35 cm. diameter) closing Nansen net, we find that when two hauls are taken together, one from 20 to 10 fathoms, and the other from 20 fathoms to the surface, the latter in many cases gives, as would be expected, the larger volume of plankton, such as, April

18th, Station III, 20-10 = 0·9 c.c., 20-0 = 1·5 c.c.; but in other cases again we find that the two hauls are roughly equal in volume, indicating that the bulk of the plankton is in the zone below 10 fathoms from the surface, as for example, April 11th, Stat. I., 20-10 and 20-0 fathoms, both = 0·6 c.c. The medium Nansen (50 cm. diameter) hauled on the same occasion from 20-0 fathoms gave 1·6 c.c.; and from this to three times seems the usual proportion between these two nets when hauled vertically together.

The medium Nansen, and also the large Nansen (100 cm. diam.) were sometimes towed horizontally, like the shear-net, when it was desired to obtain not a standard haul for statistical comparison, but a large bulk of material for some special purpose.

In comparing the hauls, taken with exactly similar nets, in the bay on the one hand and in the open sea from the yacht on the other, we find that both in spring and in autumn the hauls from the sea outside were on the whole larger than those from the bay. The difference is usually not very large, but the records seem to indicate that the amount of plankton (Diatoms, Dinoflagellates and Copepoda) in the open sea is rather greater than that in the bay during April, August and September.

WEATHER CONDITIONS.

The weather during 1911 was certainly exceptional, and this might be expected possibly to have some effect upon the amount of the plankton. The spring was cold, and the latter part of the summer (especially August) was unusually dry and warm. Professor Bassett, in his article on the Hydrography of the Irish Sea in 1911, associates these weather conditions with an unusually

early time of arrival and greater strength of the Gulf Stream Drift in our area. After two successive years of a late and weak Gulf Stream Drift associated with wet and gloomy summers, we had in 1911 an early and unusually strong invasion of Atlantic water in the Irish Sea, followed by the exceptionally dry and sunny summer. Under these unusual conditions we have decided that this cannot be regarded as a normal year, and that it is desirable to carry on the observations a little longer in the hope of obtaining a greater uniformity of results.

We insert here for reference the chart (fig. 4) of air and sea temperatures for 1911; and, for comparison, the similar chart (fig. 5) of the previous year—both made from the Port Erin Biological Station records by Mr. H. C. Chadwick. It will be noticed that, compared with 1910, the sea-temperature in 1911 was lower in spring, below 43° F. in the first week of April, but reached a higher point in summer, over 59° F. late in August. There was an almost uninterrupted rise in temperature for five months, from March 25th (the lowest sea-temperature of the year, 42° F.) to August 26th. In the air-temperatures the highest weekly average was 63° F., and an unusual number of records are above 60° F., one week in June, two in July, and four in August. In 1910 only one week (August) was over 60°, and in 1909 the highest weekly average was 58° F.

SUNSHINE.

We are only concerned with the hours of sunshine in so far as the record seems to show any co-relation with the plankton. The summer of 1911 was a notable one as regards amount of sunshine. In May, June, August, and September, the hours of sunshine at Port Erin were

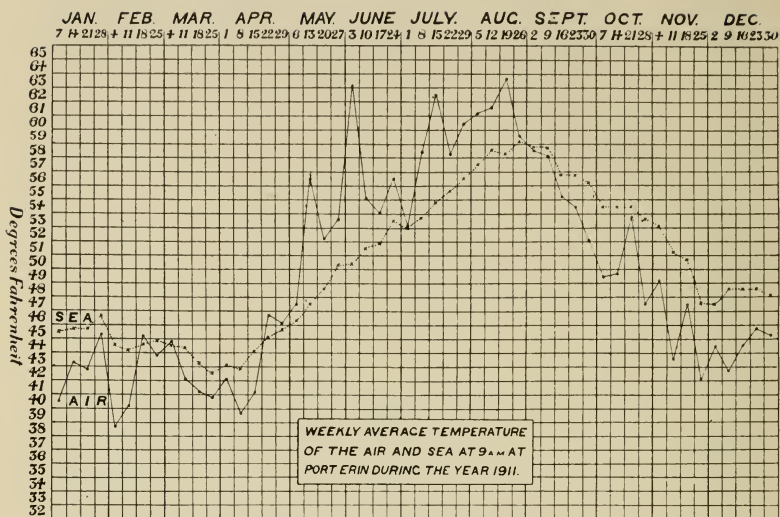


FIG. 4.

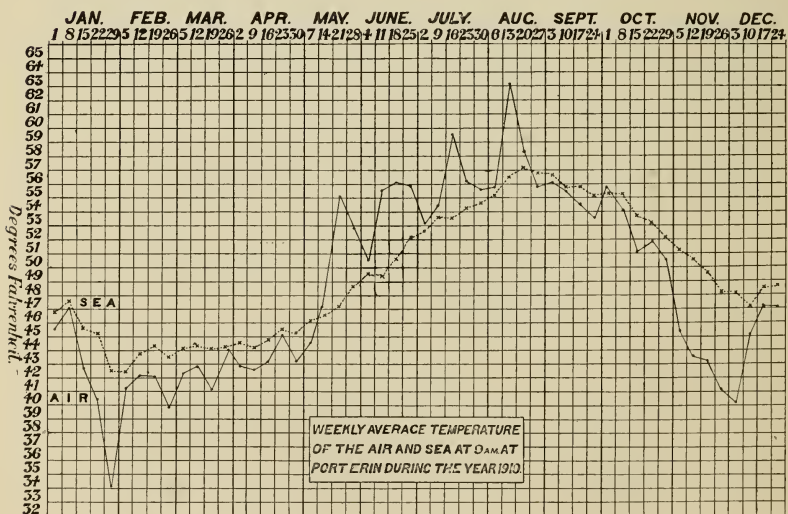


FIG. 5.

considerably above those of the corresponding months of 1910. Some other months were a little over, July was a little under, but August had no less than 194 hours recorded, as against 80 hours in 1910, and about 107 as the average of the previous four years. It is clear, however, that this summer and autumn sunshine can have no effect upon the spring phytoplankton. It is, as we showed last year, the March sunshine that may be correlated with that; and any effect of the enormous increase in the August sunshine must be looked for in the autumn and winter plankton—or possibly even in that of the following season. We have seen above that some elements of the plankton were unusually large last autumn, such as the Diatoms. This is well shown by the Diatom monthly averages per haul in the two years:

	1910.	1911.
August	850	1,998
September	676,823	928,501
October	553,601	4,742,791
November	100,262	506,729

In both years the autumnal increase begins in September, and reaches its maximum either in that month or in October and falls off in November; but in 1911 the maximum is about nine times as great as in the previous year.

Some of the groups of the zooplankton, notably Cladocera, Polychaet larvae, and Lamellibranch larvae, also show larger numbers this year in autumn and early winter than has been usual. Whether this is to be regarded as a result of the great increase in the amount of sunshine last summer, and if so whether the connection is direct or is in the case of the animals a result of the increased number of Diatoms, we are not prepared to say.

Amongst the Diatoms, in spring, species of *Chaetoceras* were in much greater abundance than usual this year, and in autumn *Biddulphia*, *Thalassiosira* and *Chaetoceras* were greater in amount than in any of the previous years of our study at corresponding times.

IN CONCLUSION.

Each additional year's work tends to confirm us in our view that, although there is a natural sequence in the distribution of the plankton throughout the year, and although there is a certain constancy in the maxima and minima for particular groups and even species, still the sequence is liable to disturbance and the maxima are affected both in time and in amount by surrounding conditions. This leads to the numerous variations which we have had to record from year to year.

Moreover, even when some constituent of the plankton is most abundant, its distribution may be irregular, in streaks or in patches, so as to destroy any such uniformity as would justify small samples being taken as representative of wide areas.

We are not yet prepared to make the promised collation and comparison of our records for the five years, that was referred to in the last Report. We shall hope to do so in a final part next year.

THE PLANKTON ON THE WEST COAST OF SCOTLAND IN RELATION TO THAT OF THE IRISH SEA.—PART II.

By W. A. HERDMAN, F.R.S., and WM. RIDDELL, M.A.

INTRODUCTORY NOTE.

In last year's Report we pointed out that our knowledge of the plankton of the western coasts of the British Islands is incomplete, by reason of a great gap extending from the North of Scotland down to the Irish Sea—a gap in our knowledge which neither the International observations on the one hand nor those of the Irish or Scottish Authorities on the other seem to fill up. With the view of obtaining data, which might in part at least bridge this gap and possibly throw light upon the question of the seasonal changes in the plankton of the Irish Sea, one of us has for several years, during the summer vacation, taken plankton hauls, both vertical and horizontal, from his yacht at various localities amongst the islands and sea lochs of the west of Scotland as far north as Portree in Skye, and as far out to the west as the Island of Barra. In our paper last year we discussed these data, and were able to show that the state of affairs in these Scottish seas, at that time of year, is somewhat different from that in the Irish Sea. At some spots in the Hebridean seas, for example, large phytoplankton hauls may be taken in July, at the time when in Manx waters the hauls are comparatively small, and are composed of zooplankton. It thus becomes of fundamental importance in connection with local sea-fisheries problems to determine more accurately the relation of the Irish Sea plankton to that of neighbouring waters to the north, to the south, and in the Atlantic outside. Such information may enable us to

estimate, for example, how far our local seasonal changes in the plankton are due to migrations or invasions from outside waters.

As the region to the south of the Irish Sea, including the English Channel, is being thoroughly investigated under the scheme of the International Council, and the necessary data will therefore naturally be available from that source, it becomes all the more important to do all that is possible to get information in regard to the condition of the plankton in the seas off the north of Ireland, and the west and north-west coasts of Scotland.

CRUISE OF 1911.

During this last summer, July and August, 1911, we were able to devote a longer time than in previous years to a more detailed survey, from the yacht "Runa," with both bottom and surface nets, of a considerable area of the west and north of Scotland. Our observations extend from the Irish Sea as far north as Noup of Noss in Shetland (from about 54° N. lat. to 60° N. lat.), and as far west as Castle Bay in Barra. They include 152 observations of the sea-temperature, and 142 of the salinity, and not only sample the water at a number of points lying off the Coast of Scotland, but also give us a series of observations across the northern entrance to the Irish Sea, as follows:—On August 22nd, when crossing from the south end of Cantyre to the north of Ireland, a series of nine temperature and salinity observations were taken, one every hour during the most important part of the traverse; and on the following day when crossing from Larne in Ireland to Port Erin, another series of eleven hourly observations was taken.

During these two months (July 7th to August

23rd) the temperatures varied from 11.2° C. to 17.8° C., and the salinities from 1.018 to 1.0276, the latter reading being a high salinity for British seas. It was recorded on August 12th in the open sea to the east of the Shetlands, but nearly as high a reading was obtained off Fair Island, off North Ronaldsay, and elsewhere in the Orkney seas, and 1.027 was obtained on July 13th and 14th off Canna and Rum on the west of Scotland.

PHYSICAL OBSERVATIONS.

The full list of our observations on temperature and salinities is appended to this paper. The list gives the dates, localities and times of the observations, the temperatures Centigrade, as taken in a cooled, clean canvas ship's bucket, rinsed and dipped from the forward part of the ship, and tested with the thermometer without delay. The next column gives the observations as taken at the time with a Kiel aræometer immersed in a cylinder of the same water from the bucket, the cylinder having been rinsed with a sample of the water before being filled. The sixth column gives the specific gravities at 17.5° C., as a result of reducing these readings at the given temperatures by means of Knudsen's Hydrographical Tables.

On looking at the first column in the list it is clear that some of the temperatures are merely due to temporary conditions of the locality—such as 17.8° C. at Loch Scavaig, in Skye, at 10.30 p.m., after a hot calm day, when the high temperature was no doubt due to the effect of the sun on the neighbouring rocks during the afternoon. On the other hand, several of the series of temperatures clearly indicate tracts of colder water. For example, in the North Channel and round the Mull of Cantyre, our readings lie between 11° and 12° , which is lower than the

temperature of the water both to the south and to the north. Then again, the following day we had water below 12° all the way up the Sound of Jura, while at Oban, and in the Sound of Lorn and Sound of Mull the temperatures were mostly between 13° and 15° . Off the north-west mainland to Cape Wrath the temperatures are between 12° and 13° , while further north in the Orkneys, off Fair Island, and off Sumburgh Head in Shetland, 14° and over is reached. Higher temperatures, about 15° , were recorded south of Skye around the Small Isles later in August, and again in the Irish Sea when returning to the Isle of Man. It is curious that the highest temperature (16.1°) recorded that day (August 23rd) in crossing from the North of Ireland to Port Erin was found in mid-channel. This observation was repeated to ensure that no mistake had been made.

The column giving the aræometer readings shows that compared with water at about ...26 in the Irish Sea the North Channel has 26.5, while the neighbourhood of Oban, the Lynn of Morven and the Sound of Mull show lower readings of from 23 to 25. Round the outside of Mull to Staffa and Iona the water is fairly constant at from 26 to 26.4. In places round the Islands south of Skye, and again in the Outer Hebrides round Barra, 27 is reached. The water off the north-west coast of Scotland is mainly between 26 and 26.8; while further north in the Orkneys, off Fair Island, and in the Shetlands 27 and over is reached. The highest reading is 27.6 in Bressay Sound on August 12th. Although our readings are, we believe, comparable with one another for the purpose of such contrasts as we have made above, we wish to state that we are inclined to regard them all as uniformly too low, and requiring a correction applied (which we have not yet determined) before they can be used for comparison with other series of observations.

PLANKTON OBSERVATIONS.

The plankton hauls, taken as frequently as possible simultaneously with the temperature and salinity observations, were in all cases made with the same nets and by the same method so that the various gatherings might be as nearly comparable as possible. All the vertical hauls were made with the smaller Nansen closing net, of No. 20 silk, and having a mouth 35 cm. in diameter. Surface hauls were sometimes taken at the same time, with ordinary open surface tow-nets made of the same silk (No. 20) as the Nansen net and of approximately the same size of mouth. The Lucas sounding machine, fitted with 200 fathoms of pianoforte wire, was used in all cases in taking the vertical hauls—down to a depth of 135 fathoms.

The list given below at page 230 shows the complete series of these plankton gatherings, which will be found to represent most of the localities dealt with in our paper in last year's Report, and we have, moreover, extended this year the observations considerably further to the north—from the Island of Skye to the Shetland Isles. We do not propose in this year's Report to make a detailed analysis of these hauls, as we hope to be able to repeat a number of the observations in the coming season; but in comparing even the brief descriptions given in our list with the characteristics of the plankton at the same localities in last year's Report, we notice certain differences which we desire to point out. For that purpose we shall group this year's 70 gatherings into seven areas comparable as far as possible with those of last year's Report, and shall indicate briefly the nature of the plankton in each and note any differences that are seen.

Date.	Time.	Locality.	Nature of Surface Hauls.	Depth. fathoms.	Nature of Vertical Hauls.
July 8.....	7.0 p.m.	Lowlandman Bay, Jura.....	Small ; zooplankton.		
" 10.....	10.30 a.m.	Off Lismore	Large ; phytoplankton.		
" 11.....	6.30 p.m.	Outside Tobermory	Moderate ; fine zoopl.	105	Moderate ; zoopl.
" 12.....	9.30 a.m.	Off Ardmore, Mull	Small ; zoopl.		
" 13.....	9.30 p.m.	Off Staffa	Small ; zoopl.		
" 14.....	9.0 a.m.	Off Iona	Very small ; zoopl.		
" 15.....	8.15 a.m.	Loch Scavaig	Moderate ; zoopl.	130	Moderate ; coarse zoopl.
" 16.....	11.30 a.m.	Between Canna and Rum	Small ; fine zoopl.		
" 17.....	2.0 p.m.	Off Hyskeir Island	Small ; zoopl.	80	Moderate ; coarse zoopl.
" 18.....	12.30 p.m.	10 miles S. of Castle Bay, Barra..	Small ; fine zoopl.		
" 19.....	8.0 p.m.	Loch Sresort, Rum	Moderate ; small zoopl.	80 & 130	Rather small ; zoopl.
" 20.....	9.30 a.m.	Between Rum and Skye	Small ; zoopl.		
" 21.....	1.0 p.m.	4 miles N. of South Rona	Larger net : medium ; zoopl.	80	Rather small ; zoopl.
" 22.....	3.0-4.0 p.m.	Dredging off Gairloch	Small ; zoopl.		
" 23.....	10.0 a.m.	Upper Loch Torridon.....	Large ; chiefly phytopl.		
" 24.....	11.30 a.m.	Outer Loch Torridon	Coarse net : large ; mixed.	70	Rather small ; zoopl.
" 25.....	1.0 p.m.	Off N. of Raasay	Small ; phytopl.	130	Rather small ; coarse zoopl.
" 26.....	All Night	Loch-na-Beiste (at Anchor)	Small ; phytopl.	60	Large ; mixed.
" 27.....	11.30 a.m.	Loch Duich	Fairly large ; phytopl.	90	Fairly large ; mixed.
" 28.....	3.45 p.m.	Loch Hourn	Small ; zoopl.	70	Fairly small ; zoopl.
" 29.....	9.30 a.m.	Loch Nevis	Small ; zoopl.		
" 30.....	9.0 a.m.	Tobermory Bay	Coarse net : large ; zoopl.	110	Fairly large ; fine zoopl.
" 31.....	12.40 p.m.	Between Kerrera and Mull	Very small ; zoopl.		
" 32.....		Mouth of Duart Bay	Small ; zoopl.	105	Medium ; zoopl. and mud.
" 33.....		Near mid-channel towards Lismore	Very small ; zoopl.		
" 34.....		(Lynn of Morven and Loch Linnhe)	Larger net : medium ; zoopl.	100	Medium ; zoopl. and mud.
" 35.....		Between Bernera Island & Ru Mor	Larger net : large ; fine zoopl.		
" 36.....		Between Sheep Id. and Kerrera	Larger net : large ; fine zoopl.		
" 37.....		Off Loch Spelve	Larger net : large ; fine zoopl.		

Date.	Time.	Locality.	Nature of Surface Hauls.	Depth. fathoms.	Nature of Vertical Hauls.
Aug. 3.....	3.0 p.m.	Upper Loch Hourn .....	.....	45	Small; zoopl.
" 4.....	4.0 p.m.	Outer Loch Hourn	Larger net: large; fine zoopl.	95	Rather small; many <i>Thysanossa</i> and fine zoopl.
" 8.....	11.30 a.m.	Off Risa Island, Orkneys	Larger net: large; fine zoopl.		
" 9.....	12 noon	Bring Deeps, Orkneys.....	Medium; mixed, much phytopl.		
" 11.....	10.0 a.m.	Moussa Sound, Shetland	Large; mixed.		
" 14.....	1.30 p.m.	Between Hoy and Cape Wrath.....	Pumped $\frac{1}{4}$ hour through fine net: small; (?) zoopl.		
" 15.....	8.0 a.m.	Head of Loch Inchar	Very large; phytopl.		
" 16.....	10.0 a.m.	Off Handa Island	Small; zoopl.	50	Moderately large; mixed.
" 17.....	1.0 p.m.	Off Ru Coyach	Medium; mixed.		
" 18.....	10.30 a.m.	Upper Loch Broom	Moderate; zoopl.		
" 19.....	1.0 p.m.	Off Loch Gruinard	Small; zoopl.	105	Moderate; zoopl.
" 20.....	5.0 p.m.	Kyle of Rona	Small; zoopl. (2 hauls).	135	Moderate; coarse zoopl.
" 21.....	3.0 p.m.	Between Rum and Eigg	Small; zoopl. ($\frac{1}{3}$ a haul).	76	Moderate; fairly coarse zoopl.
" 22.....	4.0 p.m.	N.E. of Rum	Moderate; coarse zoopl.	135	Moderate; mixed zoopl.
" 23.....	9.0 p.m.	Off Canna (in punt)	Moderate; mixed zoopl.		
" 24.....	4.0 p.m.	Off Dutchman	Moderate; mixed zoopl.		
" 25.....	3.0 p.m.	Sound of Iona	Moderate; zoopl.		
" 26.....	All night	Sound of Iona	Fairly large; zoopl.		
" 27.....	All day	Sound of Iona	Moderate; zoopl.		
" 28.....	All night	Sound of Iona	Moderate; fine zoopl.		
" 29.....	8.30 a.m.	Larne Lough	Moderate; mixed zoopl.		
" 30.....	1.30 p.m.	On course, S.S.E. from Mew Id. ...	Small; fine zoopl.		
" 31.....	3.30 p.m.	"	Larger net: medium; coarse zoopl.		
" 32.....	"	"	Small; zoopl.		
" 33.....	"	"	Larger net: medium; coarse zoopl.		

COMPARISON WITH PREVIOUS YEARS.

We have no data this year representing the Clyde Sea-Area, but can deal with all our previous localities north of Cantyre, as follows:—

Firth of Lorn.

Half a dozen hauls, ranging between Sheep Island and the Lynn of Morven—mixed hauls, but on the whole more zooplanktonic than in previous years. The Diatoms are mainly neritic. A haul taken off Lismore on July 10th is the only purely phytoplanktonic gathering in this series, and contains about fifteen millions of *Chaetoceras*. The rest of the hauls from this district were taken a couple of weeks later between the 24th and 26th of July, and it is quite likely that their more zooplanktonic character is due to the seasonal disappearance of the phytoplankton.

North End of Sound of Mull.

Hauls at Tobermory show much the same characters as in previous years, but one off Ardmore, on July 11th, presents a striking difference as it is almost a pure zooplankton, the Diatoms which were present to the number of over 40 millions per haul the previous year being represented now by only a very few *Chaetoceras* and *Coscinodiscus*, about 1600 in all. The details of the 1910 and 1911 hauls at this locality are given below for comparison. It was here, this year, that we first met with the Pteropods (*Limacina retroversa*) which were so abundant from this point onwards up to the Orkneys.

Hebridean Sea and Round the Small Islands.

Fifteen hauls represent this area, and on the whole they are more zooplanktonic than in previous years, and show a change in the nature of the few Diatoms present,

most of which are of an oceanic type (such as, *Chaetoceras densum* and *Rhizosolenia alata*). The Pteropod *Lima-cina* is present in nearly all cases in abundance (up to about 30,000 in a haul).

Sound of Sleat.

Five hauls in Loch Hourn and Loch Nevis showed very much the same characteristics as in previous years.

North of Narrows of Skye—Inner Sound and Lochs.

Nine hauls were taken between the northern part of Skye and the mainland, and fall into two series, those in the lochs being phytoplanktonic and mainly neritic, while those in the opener water of the inner sound were mainly a zooplankton. So far as they are comparable these give much the same evidence as in previous years.

This brings us to the furthest point north reached in previous years, but we add the characteristics of the remaining localities for comparison with those further south.

North-West Coast from Ru Rea to Cape Wrath.

Seven hauls taken on August 15th and 16th show mixed gatherings, with the exception of a haul in Loch Inchar which is a typical phytoplankton containing nearly 50 millions of Diatoms (the details of this haul are given below). Some are more zooplanktonic than others, but in general there are far more Diatoms here than in the Hebridean seas south of Skye.

From Cape Wrath to the Shetland Isles.

Four hauls, two phytoplanktonic and two mixed gatherings containing both animals and plants, of both neritic and oceanic species, show at least that the Diatoms had not disappeared by the middle of August at this furthest north point in the British Seas.

NOTEWORTHY SPECIES AND HAULS.

There are a few of the species occurring in this year's hauls that are of special interest. In the Diatoms, *Skeletonema costatum*, which had been found in great abundance by George Murray in 1896, in Loch Etive, and which we only met with rarely in previous years, occurs more plentifully in our gatherings this year in the Mull district. Amongst new records we have *Nitzschia closterium* (Loch Scavaig, Skye), *Chaetoceras atlanticum* (Moussa Sound) and *Pyrocystis lunula* (Loch Hourn and Loch Nevis).

In Upper Loch Torridon, on July 19th, with water of very low salinity (1·018)—due no doubt to mixture with fresh water from the land—we got two remarkable hauls (coarse and fine nets) containing, along with a

Upper Loch Torridon, 19/7/11.

	Fine Net.	Coarse Net.
<i>Calanus helgolandicus</i>	6	—
<i>Pseudocalanus elongatus</i>	×	—
Nauplii	10,000	15,700
Fish eggs	—	9
<i>Oikopleura</i>	136,500	42,000
Tintinnidae	420,000	388,500
<i>Ceratium furca</i>	×	—
„ <i>tripos</i>	—	5,250
<i>Peridinium</i> spp.	2,052,500	351,700
<i>Dinophysis</i> sp.	189,000	21,000
<i>Chaetoceras boreale</i>	1,470,000	1,454,000
„ <i>constrictum</i>	1,102,500	141,700
„ <i>debile</i>	—	241,500
„ <i>decipiens</i>	2,782,500	5,076,700
„ spp.	16,117,500	2,709,000
<i>Nitzschia delicatissima</i>	334,365,000	328,125 000
„ <i>seriata</i>	73,500	36,700
<i>Rhizosolenia semispina</i>	346,500	871,500
<i>Skeletonema costatum</i>	84,000	84,000
<i>Thalassiosira decipiens</i>	378,000	—
„ <i>gravida</i>	462,000	771,700

number of the usual marine Diatoms, an enormous quantity of *Nitzschia delicatissima* which we estimate at well over three hundred million individuals in each net. In this case the size of the mesh seemed to make so little difference in the nature and amount of the catch that we

think it well to give the details of these two hauls here as a record of this unusual occurrence.

One of the most noticeable features of this year's gatherings was the abundance and wide distribution of the Pteropod *Limacina retroversa*. After we first came upon it at Tobermory in July, it was practically universal in its presence and extended from the north of Mull up to the Orkneys and Shetlands. It was only absent in a few of the more sheltered and land-locked localities. The numbers in a haul vary from about 400 (at Tobermory) to 30,000 (South of Skye and also at Loch Scresort in Rum).

This Pteropod is a boreal Atlantic form which is found commonly off the south and west of Ireland—where it is a common food of the mackerel. Dr. T. Scott has also found it as a common food for herrings from the west coast of Scotland. It does not extend up to Arctic seas; it is rare in the English Channel, does not reach the North Sea and apparently does not pass up through St. George's Channel.

We have selected a few other notable hauls to give here in detail:—

1. Off Ardmore, for comparison with the previous year.
2. Between Canna and Rum, again for comparison.
3. Loch Inchard, to show an undoubted phytoplankton far north in the middle of August.
4. Moussa Sound, Shetland—one of our most northerly hauls, and again a phytoplankton.

1. Off Ardmore, N. of Mull.

July 18th, 1910. July 11th, 1911.
86 fathoms. 105 fathoms.

Chaetoceras curvisetum	18,571,450	—
„ debile	6,571,450	—
„ decipiens	2,071,440	—
„ spp.	20,357,150	1,260
Coscinodiscus radiatus	2,500	420
Ditylium brightwellii	625	—
Guinardia flaccida	71,425	—
Lauderia borealis	357,145	—
Nitzschia seriata	1,642,850	—
Pleurosigma sp.	1,250	—
Rhizosolenia semispina	464,285	—
„ setigera	17,860	—
„ shrubsolii	190,475	—
„ stolterfothii	2,142,860	—
Skeletonema costatum	857,145	—
Thalassiosira gravida	1,428,575	—
„ nordenskioldii	571,430	—
Peridinium spp.	10,000	1,260
Ceratium furca	625	—
„ tripos	625	840
Tintinnidae	13,440	840
Medusae	13	6
Sagitta	25	30
Tomopteris	—	1
Polychaet larvae	625	—
Plutei	3,600	—
Gastropod larvae	7,500	—
Lamellibranch larvae	5,000	—
Limacina retroversa	—	9,360
Schizopoda	6	×
Evadne nordmanni	—	525
Calanus helgolandicus	95	430
Pseudocalanus elongatus	5,100	2,100
Temora longicornis	935	3,150
Oithona similis	625	1,150
Copepoda juv.	1,875	—
Nauplii	25,625	8,800
Oikopleura	3,230	420

This year's haul (right hand column) shows a somewhat scanty zooplankton, last year's a very abundant phytoplankton. These two hauls show clearly that the main difference is not the presence of additional animals in the zooplankton, but merely the absence of the Diatoms.

2. Between Canna and Rum.

July 14th, 1910. July 13th, 1911
128 fathoms. 130 fathoms.

Chaetoceras constrictum	5,714,300	—
„ curvisetum	41,714,200	—
„ debile	5,285,700	—
„ decipiens	3,857,140	1,050
„ spp.	15,214,275	—
Coscinodiscus radiatus	4,690	420
Guinardia flaccida	1,040	—
Lauderia borealis	23,960	—
Nitzschia seriata	357,140	—
Pleurosigma sp.	×	—
Rhizosolenia semispina	142,750	840
„ shrubsolii	29,175	—
„ stolterfothii	17,715	—
„ styliformis	—	420
Ceratium fusus	1,040	—
„ intermedium	—	200
„ tripos	5,210	3,350
Peridinium spp.	18,750	—
Tintinnidae	22,920	630
Medusae	50	—
Sagitta	6	7
Polychaet larvae	×	200
Plutei	520	—
Gastropod larvae	56,270	—
Limacina retroversa	—	8,400
Calanus helgolandicus	500	520
Pseudocalanus elongatus	3,125	2,100
Acartia clausi	1,215	—
Oithona similis	4,430	3,150
Nauplii	23,445	9,650
Evadne nordmanni	—	200
Oikopleura	2,080	2,300

This again shows a zooplankton in 1911 at a locality where at the same time of year in 1910 there was a marked phytoplankton. The difference is due again simply to the absence of the millions of Diatoms that characterised the locality in 1910—and the presence of Pteropods in 1911.

3. L. Inchard, near Cape Wrath, 15/8/11. Surface.

<i>Chaetoceras boreale</i>	378,000
„ <i>breve</i>	315,000
„ <i>constrictum</i>	11,250,000
„ <i>criophilum</i>	2,333,400
„ <i>debile</i>	22,475,000
„ <i>decipiens</i>	1,102,500
„ <i>densum</i>	1,000,000
„ <i>didymum</i>	16,400
„ <i>teres</i>	95,750
„ <i>spp.</i>	7,500,000
<i>Corethron criophilum</i>	400
<i>Nitzschia seriata</i>	107,000
<i>Rhizosolenia semispina</i>	43,300
„ <i>stolterfothii</i>	33,600
„ <i>styliformis</i>	12,600
<i>Thalassiosira gravida</i>	7,500
„ <i>nordenskioldii</i>	2,500
<i>Peridinium spp.</i>	10,000
<i>Ceratium fusus</i>	200
„ <i>intermedium</i>	8,000
„ <i>lineatum</i>	420
„ <i>longipes</i>	3,350
„ <i>tripos</i>	11,350
<i>Tintinnidae</i>	10,000
<i>Evadne nordmanni</i>	840
<i>Pseudocalanus elongatus</i>	420
<i>Acartia clausi</i>	840
<i>Oithona similis</i>	1,450
<i>Nauplii</i>	6,000
<i>Oikopleura</i>	630

This is a typical phytoplankton. It was taken late in the summer and it is the furthest north of our gatherings off the mainland of Scotland. The number of Diatoms is enormous, the gathering is dull green and dense, and, as the list shows, a few species of *Chaetoceras* are represented by nearly fifty millions of individuals.

4. Moussa Sound, Shetland, 11/8/11. Surface.

<i>Bacteriastrium delicatulum</i>	53,000
<i>Chaetoceras atlanticum</i>	42,800
" <i>boreale</i>	32,750
" <i>breve</i>	1,562,500
" <i>cinctum</i>	201,600
" <i>constrictum</i>	176,400
" <i>criophilum</i>	1,193,000
" <i>debile</i>	5,812,500
" <i>decipiens</i>	1,250,000
" <i>didymum</i>	3,625,000
" <i>teres</i>	438,500
" <i>spp.</i>	29,062,500
<i>Dactyliosolen tenuis</i>	54,800
<i>Eucampia zodiacus</i>	45,350
<i>Leptocylindrus danicus</i>	37,800
<i>Nitzschia seriata</i>	7,687,500
<i>Rhizosolenia alata</i>	118,450
" <i>stolterfothii</i>	141,100
" <i>styliformis</i>	25,200
<i>Thalassiosira gravida</i>	1,900
" <i>nordenskioldii</i>	115,900
<i>Dinophysis</i> sp.	3,150
<i>Peridinium</i> spp.....	44,700
<i>Ceratium furca</i>	19,500
" <i>fuscus</i>	41,600
" <i>intermedium</i>	103,300
" <i>lineatum</i>	171,350
" <i>longipes</i>	2,500
" <i>macroceros</i>	8,200
" <i>tripos</i>	252,000
<i>Calanus helgolandicus</i>	10
<i>Pseudocalanus elongatus</i>	630
<i>Acartia clausi</i>	8,800
<i>Centropages hamatus</i>	315
<i>Oithona similis</i>	6,900
<i>Nauplii</i>	3,150
<i>Evadne nordmanni</i>	1,250
<i>Podon intermedium</i>	630
<i>Decapod larvae</i>	10
<i>Sagitta</i>	1
<i>Limacina retroversa</i>	5,000
<i>Echin. plutei</i>	2,500
<i>Tintinnidae</i>	14,500
<i>Oikopleura</i>	630
Fish eggs	3

This far-north gathering, in the Shetland Isles, in August, is an undoubted phytoplankton with about fifty millions of Diatoms. It has also, however, an unusually large number of Dinoflagellates, and a fair number of Copepoda and other animals, including 5,000 of the Pteropod *Limacina retroversa*.

The main points of difference between this year's hauls and those of former years are off Ardmore at the north end of the Sound of Mull, and in the sea around the Small Isles. In both places the phytoplankton formerly present is now replaced by zooplankton. Moreover, round the Small Isles the Diatoms are now mainly of oceanic type in place of being neritic forms. Other localities are much the same as in previous years; but in the new ground, further north, there is more phytoplankton than in the seas south of Skye.

During all this time (July 8th to August 23rd) the plankton at Port Erin, in the Irish Sea, was an undoubted zooplankton composed chiefly of Copepoda and having few or no Diatoms.

The facts, such as they are, all seem to support the suggestion, put forward last year, that the most probable explanation of the presence of huge masses of Diatoms in the Scottish Seas in summer is that the phytoplankton remains longer and passes off more slowly as one goes further north.

Appendix—List of the Physical Observations.*

Date.	Time.	Locality.	Temp. C.	Aräometer	$\rho_{17.5^{\circ}}$
July	7.....	9.40 p.m. Port Erin Bay	14°	1.0262	25.5
„	8.....	3.0 a.m. Off Bradda Head	12.6°		
		4.0 a.m. Off Contrary Head	12.5°	1.026	25.04
		9.0 a.m. Off Portpatrick	11.2°		
		11.30 a.m. N.W. by W. of Corsewall	11.4°		
		12.30 p.m. 10 miles S. of Cantyre	11.3°	1.0264	25.24
		2.0 p.m. W. of Mull of Cantyre	11.8°	1.0265	25.42
		3.30 p.m. E. by S. of the Mull Lt. House	12.2°	1.0262	25.19
		4.45 p.m. W. of Gigha Buoy	12.4°		
		7.0 p.m. Lowlandman Bay, Jura.....	12.2°	1.0256	24.59
„	9.....	9.15 a.m. 2 miles N. of Lowlandman Bay ...	11.2°		
		10.30 a.m. Off Ruadh	11.3°	1.0264	25.24
		11.30 a.m. Off Scarba	11.8°	1.0262	25.13
		12 noon Off Easdale	11.8°	1.0262	25.13
		10.30 p.m. Oban Bay.....	13.4°		
„	10.....	9.0 a.m. Oban Bay.....	12.8°	1.0256	24.69
		10.30 a.m. Off Lismore	14.8°	1.0242	23.66
		4.15 p.m. Sound of Lorn	15.2°	1.024	23.54
		4.45 p.m. Lynn of Morven	15.4°	1.0234	22.98
		5.30 p.m. Sound of Mull	13°	1.0254	24.53
		6.30 p.m. Outside Tobermory	12.2°	1.0258	24.79
„	11.....	8.0 a.m. Tobermory Bay	13.8°		
		9.30 a.m. Off Ardmore, Mull	13.6°	1.026	25.23
		11.0 a.m. Off Cailliach Point	13.4°	1.0262	25.39
		3.0 p.m. Off Staffa	15.5°	1.0261	25.69
		9.30 p.m. Off Iona	12.3°	1.0264	25.4
„	12.....	9.0 a.m. Off Iona	12.3°	1.0262	25.21
		3.0 p.m. Off Cailliach	13.2°	1.0264	25.56
		4.25 p.m. 3 miles S.W. Muck Id.	15.2°	1.0263	25.83
		6.10 p.m. Off Loch Scresort, Rum	15.6°	1.0261	25.71
		10.30 p.m. Loch Scavaig, Skye	17.8°	1.0238	23.87
„	13.....	8.15 a.m. Loch Scavaig	14.5°		
		11.30 a.m. Between Canna and Rum	13.5°	1.027	26.2
		2.0 p.m. Off Hyskeir Id.	14.6°	1.0267	26.11
		4.10 p.m. Between Hyskeir and Barra	15.8°	1.0265	26.14
		10.30 p.m. Castle Bay, Barra	13.9°	1.027	26.28
„	14.....	11.0 a.m. Vatersay Sound	12.9°	1.027	26.1
		12.30 p.m. 10 miles S. of Castle Bay	14.8°	1.0266	26.04
		4.0 p.m. N. of Canna	12.4°	1.027	26.01
		8.0 p.m. Loch Scresort, Rum	13.9°	1.0262	25.49
„	15.....	9.0 a.m. Loch Scresort	13.6°		
		9.30 a.m. Between Rum and Skye	13.1°	1.026	25.14
		12.20 p.m. Entering Sleat Sound.....	12.2°	1.026	24.99
		3.0 p.m. Outside Narrows of Skye	12.6°	1.0256	24.66
		4.0 p.m. Off Croulin Island	14.2°	1.0254	24.74
„	16.....	12.30 p.m. Portree, Skye	11.6°	1.0266	25.48
		6.15 p.m. Portree	13.4°	1.026	25.19
„	17.....	10.50 a.m. Portree	12°	1.0266	25.55
		11.40 a.m. Off Holm Island	12.2°	1.0266	25.58
		1.0 p.m. 4 miles N. of S. Rona	12.6°	1.0266	25.65

* As we have stated above (p. 228), we have now reason to think that all our aräometer readings are consistently too low, and require a correction to be applied before they can be compared with other series.

Date.	Time.	Locality.	Temp. C.	Aræometer	$\rho_{17.5^{\circ}}$
July 18.....	8.40 a.m.	Near mouth of Gairloch	12.8°	1.0252	24.3
	10.15 a.m.	Off Ru Rea	12.6°	1.0264	25.45
	11.0 a.m.	Loch Ewe	12.4°	1.026	25.02
	6.0 p.m.	Entering Loch Torridon	13.2°	1.0256	24.76
„ 19.....	10.0 a.m.	Upper Loch Torridon.....	13.8°	<1.018	<17.34
	11.30 a.m.	Outer Loch Torridon	12.4°	1.026	25.02
	1.0 p.m.	Off N. of Raasay	11.9°	1.026	24.95
„ 20.....	8.30 a.m.	Loch-na-Beiste	12.2°	1.0262	25.19
	8.50 a.m.	Off Loch-na-Beiste	12°	1.0254	24.37
	9.10 a.m.	Loch Alsh.....	12.2°	1.0248	23.8
	11.30 a.m.	Loch Duich	15°	<1.018	<17.54
	3.45 p.m.	Loch Hourn	14.2°	1.0242	23.56
	4.45 p.m.	Sound of Sleat.....	13.5°	1.026	25.21
„ 21.....	8.40 a.m.	Tarbet, Loch Nevis	13.0°	1.0256	24.73
	9.30 a.m.	Loch Nevis	13.4°	1.0258	24.99
	1.0 p.m.	Between Eigg and Ardnamurchan	12.8°	1.0262	25.29
„ 22.....	9.0 a.m.	Tobermory Bay	12.9°	1.0246	23.72
„ 23.....	11.30 a.m.	Oban	12.3°	1.0262	25.21
	2.40 p.m.	Oban	12.5°	1.0258	24.84
	5.30 p.m.	Oban	12.5°	1.0256	24.65
	8.30 p.m.	Oban	12.6°	1.0258	24.86
„ 24.....	11.30 a.m.	Off Loch Spelve	11.8°	1.026	24.93
„ 25.....		Lynn of Morven and Loch Linnhe,	12°	1.0254	24.37
		between Bernera Island and	13°	1.024	23.15
		Ru Mor	13.2°	1.0238	22.98
„ 26.....		Between Sheep Island and Kerrera	12°	1.0264	25.35
Aug. 2.....	11.30 a.m.	Sound of Mull, off Green Islands...	12.9°	1.0255	24.62
	12.45 p.m.	N. end of Sd. of Mull, off Ardmore	13.2°	1.026	25.16
	4.30 p.m.	S. of Sd. of Sleat, between Eigg and	13.1°	1.0264	25.54
		Sleat Pt., open sea			
„ 3.....	12 noon	Isle Ornsay	12.8°	1.026	25.09
	3.0 p.m.	Upper Loch Hourn.....	14°	1.0248	24.11
	4.0 p.m.	Outer Loch Hourn	14°	1.025	24.31
„ 4.....	10.0 a.m.	Sound of Sleat.....	13.6°	1.0259	25.13
	10.30 a.m.	Sound of Kilrea	13.2°	1.0257	24.86
	10.50 a.m.	Loch Alsh.....	12.95°	1.026	25.11
	11.30 a.m.	Off Croulin	12.35°	1.0257	24.72
	4.0 p.m.	Off Ru Rea	13°	1.0265	25.62
„ 5.....	11.30 a.m.	Mouth of Loch Ewe	13°	1.0251	24.24
	4.0 p.m.	Off Handa Island	12.6°	1.0266	25.65
„ 6.....	8.0 a.m.	Loch Erribol	12.6°	1.0267	25.75
	11.0 a.m.	3 miles off Tongue	13.2°	1.0268	25.95
	1.0 p.m.	Half-way to Hoy	13.2°	1.0268	25.95
„ 7.....	10.0 a.m.	Off Stromness	14°	1.0261	25.4
„ 8.....	11.30 a.m.	Risa Island	13°	1.027	26.11
	6.0 p.m.	Scapa Bay	15°	1.0268	26.28
„ 9.....	12 noon	Bring Deepes	13°	1.0268	25.91
„ 10.....	9.0 a.m.	Off Copinsay	13°	1.0268	25.91
	3.0 p.m.	Off S. of Fair Island	13.5°	1.027	26.2
	6.0 p.m.	Off Sumburgh Head	14.1°	1.0271	26.41
„ 11.....	10.0 a.m.	Moussa Sound	12.9°	1.0273	26.4
	6.0 p.m.	Bressay Sound.....	13.0°	1.0274	26.51
„ 12.....	6.30 a.m.	Bressay Sound.....	12.6°	1.0276	26.63
	10.0 a.m.	Off Sumburgh Head	14.1°	i.027	26.31
	1.0 p.m.	Off Fair Island	14.2°	1.0272	26.53
	4.0 p.m.	Off N. Ronaldsay	12.4°	1.0272	26.21
	7.0 p.m.	Off Noup Head	12.9°	1.0268	25.9

Date.	Time.	Locality.	Temp. C.	Aræometer.	$P_{17-5^{\circ}}$
Aug. 14.....	11.0 a.m.	Off Old Man of Hoy	14°	1-0266	25-89
	1.30 p.m.	Between Hoy and Cape Wrath ...	14-2°	1-0267	26-03
	4.30 p.m.	Off Cape Wrath	12-9°	1-027	26-1
„ 15.....	8.0 a.m.	Head of Loch Inchard	12-8°	1-0265	25-59
	10.0 a.m.	Off Handa Island	12-6°	1-027	26-04
	1.0 p.m.	Off Ru Coyach	13-2°	1-0266	25-75
„ 16.....	9.30 a.m.	Off Ullapool	13-2°	1-0263	25-46
	10.30 a.m.	Upper Loch Broom	15°	1-025	24-49
	1.0 p.m.	Off Loch Gruinard	13-6°	1-0263	25-53
	2.30 p.m.	Off Ru Rea	13°	1-0267	25-81
	5.0 p.m.	Kyle of Rona	13-8°		
„ 17.....	9.30 a.m.	Loch-na-Beiste	13-4°	1-0258	24-99
	12 noon	Sound of Sleat.....	15-4°	1-0255	25-07
	4.0 p.m.	N.E. of Rum	15°	1-0258	25-29
	6.0 p.m.	Off Canna	15°	1-0264	25-89
„ 18.....	10.0 a.m.	Off Canna Harbour	14°	1-0264	25-7
	12 noon	Between Rum and Coll	14°	1-0264	25-7
	4.0 p.m.	Off Dutchman	14°	1-0262	25-5
„ 19.....	3.0 p.m.	Sound of Iona	14-2°	1-0259	25-24
„ 20.....	10.0 a.m.	Sound of Iona	14-2°	1-0259	25-24
	8.0 p.m.	Sound of Iona	14-2°	1-0257	25-04
„ 21.....	7.30 a.m.	Sound of Iona	13-9°	1-0259	25-19
	9.0 a.m.	Off Staffa	14°	1-0258	25-1
	11.0 a.m.	Off N. of Mull	14-6°	1-026	25-41
	1.0 p.m.	Sound of Mull	14-2°	1-0257	25-04
	3.0 p.m.	Between Lismore and Kerrera ...	15-3°	1-0244	23-96
„ 22.....	6.0 a.m.	Oban Bay	13-5°	1-0258	25-01
	10.0 a.m.	Off Crinan	13-4°	1-026	25-19
	1.0 p.m.	Off Lowlandman Bay	14-6°	1-0262	25-61
	3.30 p.m.	Between S. of Islay and S. of Gigha	15-2°	1-026	25-53
	4.30 p.m.	Betw. S. of Islay & Machrihanish.	13-7°	1-0261	25-35
	5.30 p.m.	Between Cantyre and Rathlin Id....	14-4°	1-026	25-37
	6.30 p.m.	Off Garron Pt., Antrim	14-3°	1-0259	25-26
	7.30 p.m.	Off Carnlough Bay, N. of Maidens	13-4°	1-0262	25-39
	8.30 p.m.	Off mouth of Larne Lough	13-7°	1-0261	25-35
„ 23.....	8.30 a.m.	Larne Lough	13-4°	1-0261	25-29
	9.30 a.m.	Off Muck Island	13-5°	1-0261	25-31
	10.30 a.m.	Off Mouth of Belfast Lough	14-5°	1-0258	25-19
	11.30 a.m.	Off Donaghadee	14°	1-026	25-3
	12.30 p.m.	On Course S.S.E. from Mew Id. ...	13-9°	1-0259	25-19
	1.30 p.m.	„	14-8°	1-0256	25-05
	2.30 p.m.	„	14-4°	1-0258	25-17
	3.30 p.m.	„ (twice)	16-1°	1-0255	25-21
	4.30 p.m.	„	15-4°	1-0258	25-37
	5.30 p.m.	„ (8 miles off Bradda)	15-7°	1-0257	25-33
	6.30 p.m.	„ (1 mile off Bradda)	15-5°	1-026	25-59
„ 25.....	3.0 p.m.	1 mile N.W. Bradda	14-6°	1-0258	25-21
		Station I, 5 miles out	14-7°	1-0258	25-23
		„ (a mile away)	14-6°	1-0259	25-31
		Station III.	14-6°	1-0258	25-21
„ 26.....	10.30 a.m.	1 mile N.W. Bradda	14-6°	1-0257	25-11
		Station I.	14-7°	1-0258	25-23
		„ III.	14-5°	1-0258	25-19
„ 28.....		„ I.	14-8°	1-0259	25-35
		„ III.	14-9°	1-0259	25-37

	Date.	Time.	Locality.	Temp. C.	Aräometer	$\rho_{17.5^{\circ}}$
Sept.	8.....	Forenoon	Station I.	15.7°	1.0258	25.43
			" III.	15.5°	1.026	25.59
"	9.....	4.0 p.m.	Off Niarbyl	15°	1.0258	25.29
"	11.....	Afternoon	Off Dalby	15.2°	1.026	25.53
"	12.....	Forenoon	Station I.	14.6°	1.0262	25.61
			" III.	14.5°	1.0264	25.79
"	13.....	Forenoon	Station I.	14.6°	1.0262	25.61
			" III.	14.7°	1.0262	25.63
"	15.....	Forenoon	Off Niarbyl	11.2°	1.0262	25.03
"	16.....	Forenoon	Station I.	11.8°	1.026	24.93
			" III.	12°	1.026	24.96
"	18.....	Forenoon	Station I.	14.4°	1.0262	25.57
			" III.	14.5°	1.026	25.39
"	19.....	Forenoon	" III.	14.4°	1.0258	25.17



S.Y. "Runa" at Hoswick Fishery Station, Shetland, August 10th, 1911.

NOTE ON THE WEST COAST LOBSTER FISHERIES.

By J. TRAVIS JENKINS, D.Sc., Ph.D.
Superintendent of Sea Fisheries.

In the Annual Report of Proceedings under Acts relating to Sea Fisheries for the year 1910, issued by the Board of Agriculture and Fisheries in 1912, there is a memorandum on the size, sex and condition of Lobsters, which, as it contains deductions based on erroneous statistics, needs some correction.

The Memorandum in question has, so far as the Northumberland district is concerned, been somewhat severely criticised by Professor Meek. The Board maintain that it is better to raise the minimum size limit to nine inches than to protect the berried female. Prof. Meek points out the fallacy in the Board's reasoning.* As a matter of fact, in the Lancashire and Western District the minimum size limit is nine inches and the berried lobster is protected, so the arguments on either side do not concern us much.

The West Coast of England and Wales is admittedly not an important lobster fishing centre. On this coast fishing for lobsters and crabs is carried on in open boats, and the prevailing westerly and south-westerly winds put a stop to fishing in the winter months. Not only is it frequently unsafe to venture out to sea in open boats for days or even weeks at a time, but the lobster "pots" are frequently washed up on shore or destroyed in other ways by strong winds and gales.

* Report by Professor Meek on the Memorandum issued by the Board of Agriculture and Fisheries, on the size, sex and condition of Lobsters. Printed by order of the Northumberland Fisheries Committee, 16th April, 1912.

The Board publish the following statistics in the Memorandum as to the number of lobsters caught on the West Coast in the years stated :—

1900	...	104,062	1905	...	69,572
1901	...	98,826	1906	...	67,997
1902	...	94,943	1907	...	51,009
1903	...	64,174	1908	...	53,706
1904	...	78,237	1909	...	46,806

If this table be correct then there is clear evidence of a rapid and serious decline in the yield of the West Coast lobster fisheries, a decline which if not checked will lead to the complete extinction of the fisheries in another nine years or so.

The Board state :—“ On the West Coast the landings in the second period of five years are 151,152, or 34·3 per cent. less than those in the first, and the decrease from year to year is fairly steady, 1909 showing a decrease of over 50 per cent. on 1900.”

“ There is reason to believe that the statistics have been fuller and more accurate of late years, so that the decrease shown . . . notably for the West Coast is not at all likely to be due to less efficient collection of statistics.”

While this last statement may be perfectly true it does not exclude the possibility of error. The decline may be due, and as I shall endeavour to show is really due, to the more efficient collection of statistics and not to a falling off in the fisheries. The fact is the earlier totals for the West Coast are unfortunately fictitious and are far too high.

If this be not the case then it is obvious that the measures of protection, or the methods of enforcing them, on the West Coast are not sufficient to preserve the

lobster fisheries from a rapidly approaching extinction. At the rate of exhaustion shown in the Board's Memorandum there will be no lobsters left on the West Coast in 1920.

That the error in the Board's statistical returns is a very serious one may be seen from the study of two localities for which, fortunately, statistics are available for the years 1900-9. These two places or ports are Pwllheli and Holyhead. For ports outside the Lancashire and Western District the details are not available.

Take Pwllheli first. The total number of lobsters returned as landed at Pwllheli from 1900 to 1904 are as follows:—

1900	...	8,100	1903	...	3,570
1901	...	3,000	1904	...	3,692
1902	...	3,172			

As a matter of fact, these lobsters are caught off the Lleyn promontory of Carnarvonshire, principally at Bardsea Island, but as they pass through Pwllheli on their way to the market they are "returned" from that port.

As I showed on a former occasion* the records for Pwllheli previous to the middle of 1902 are undoubtedly false and consequently misleading. In all probability the statistics of lobsters for Pwllheli are from 4,500 to 5,000 too high for 1900; that is, there is in one single port an error of from 4 to 5 per cent. of the total figures for the whole of the West Coast for that year. Since statistics are collected from 40 fishing ports on the West Coast, it will be seen that the possibilities of error are fairly large.

As another example, take the number of lobsters returned for Holyhead:—

* Lancashire and Western Sea Fisheries. Superintendent's Report for the Quarter ending December, 1904. Preston, 1905.

1900	...	2,960	1905	...	1,050
1901	...	3,127	1906	...	1,762
1902	...	2,605	1907	...	1,593
1903	...	2,189	1908	...	686
1904	...	1,378	1909	...	1,400

Now it is practically certain that the earlier totals are sheer guesswork. From an intimate knowledge of the district I have no hesitation in saying that the totals for 1900 and 1901 are at least twice as high as they ought to be.

If the official statistics were available in detail it is possible that other similar instances could be quoted. The above remarks are based on the assumption that the annual totals of lobsters (in the Board's memorandum of 1910) have been correctly abstracted from the Annual Reports furnished by the Central Authority. But have they?

A comparison with these annual reports does not tend to reassure one that such is the case. Up to, and including 1902, the official fishery statistics were published by the Board of Trade under the title of "Statistical Tables and Memorandum relating to the Sea Fisheries of the United Kingdom."

In and since 1903 the Board of Agriculture and Fisheries have published the official statistics in the "Annual Report of Proceedings under Acts relating to the Sea Fisheries."

On comparing the totals in the Board's Memorandum with these official records, we get the following result:—

RETURN OF LOBSTERS LANDED (WEST COAST).

	Memorandum of Board of Agriculture and Fisheries. (1910).	Official Statistics. (From Annual Reports.)	Statistical Tables and Memorandum relating to the Sea Fisheries of the United Kingdom. (Board of Trade).
1900.....	104,062	155,868	
1901.....	98,826	160,746	
1902.....	94,943	163,183	
1903.....	64,174	138,404	
1904.....	78,237	115,218	
1905.....	69,572	69,572	Annual Report of Proceed- ings under Acts relating to the Sea Fisheries. (Board of Agriculture and Fisheries.)
1906.....	67,997	67,997	
1907.....	51,009	51,009	
1908.....	53,706	53,706	
1909.....	46,806	46,806	

According to this there is a considerable difference in the various official estimates up to and including 1904. There may, of course, be some explanation of these discrepancies in the years 1900-4.

The total number of lobsters landed in England and Wales is also variously given.

RETURN OF LOBSTERS (ENGLAND AND WALES).

	Memorandum of Board of Agriculture and Fisheries. (1910).	Other Official Returns (as above).
1900.....	602,346	654,152
1901.....	588,571	650,491
1902.....	580,496	648,736
1903.....	475,121	549,351
1904.....	515,034	552,015
1905.....	502,673	502,673
1906.....	520,657	520,657
1907.....	495,326	495,326
1908.....	512,478	512,478
1909.....	546,805	546,805

As regards the detailed figures furnished by the Lancashire and Western Committee, the Board have

again fallen into serious errors. For instance, take the statement (p. lxxxiv):—

“The ratio of non-berried females to males points unmistakably to the widespread occurrence of stripping.”

As can easily be proved by a reference to the Board's own figures, it points unmistakably to nothing of the sort.

The number of non-berried females and males in the Lancashire and Western District is given in Table IX. The next table above is for Cornwall (Table VIII):—

CORNWALL.			LANCASHIRE & WESTERN.	
	Non-berried Females.	Males.	Non-berried Females.	Males.
Under 9 in.	986	815	11	0
„ 10 „	1,061	831	1,643	1,504
„ 11 „	723	619	1,386	1,337
„ 12 „	598	442	1,102	1,028
Over 12 „	481	415	759	643
	3,849	3,122	4,901	4,512

That is to say the ratio of non-berried females to males is in Cornwall 123·2 : 100, and is in Lancashire and Western 108·6 : 100.

So that if these figures prove that stripping is prevalent in the Lancashire and Western District, they also prove that stripping is still more prevalent in the Cornwall District, and this is very strange since there is no restriction in Cornwall on the landing of berried lobsters!

As a matter of fact, the Lancashire and Western statistics were obtained from two distinct sources, which should have been kept distinct and not lumped together as in Table IX. The statistics from Pwllheli were obtained by our Fishery officer as a result of measurements and determinations of sex of the lobsters landed by the fishermen. Consequently, lobsters under nine

inches and berried lobsters, the landing of which is illegal in the District, are excluded. (I find, however, that the Fishery officer includes 7 berried lobsters landed on May 27 (2), June 17, June 24 and July 7 (3), 1908, by a fisherman, who was warned on the first occasion and prosecuted on the other three.) A few measurements were made in similar manner by the Fishery officer at Carnarvon and Bangor.

The statistics at New Quay relate to the fishing carried on by an individual fisherman (our Fishery officer at New Quay), who recorded *all* the lobsters found in his "pots." Consequently, lobsters under nine inches and berried females are both included. The total number of lobsters of all kinds caught by this single fisherman will, of course, bear but a small ratio to those landed and measured at Pwllheli. At New Quay the berried lobsters taken in the pots were labelled before liberation, but in no instance was one recaptured.

To group together returns obtained from entirely different sources, and from different methods, as was done by the Board in Table IX is misleading.

The fallacy of the Board's arguments, which lead them to conclude there is widespread "stripping" of berried lobsters in this district, is seen when the detailed statements are examined.

LANCASHIRE AND WESTERN LOBSTERS (1907-9).—DETERMINATIONS
OF SEX, ETC.

	From all sources.	The Records of one Fisherman
Berried females	29	21
Non-berried females	4,901	385
Males	4,512	362
	9,442	768

Now the proportion of non-berried females to males is pretty much the same in the two tables, viz., 108·6 to 100 in the first, and 106·3 to 100 in the second, so that stripping is to be expected as much in the second instance as in the first.

But as the figures in the second column were supplied by our Fishery officer at New Quay who fished himself, they exclude all possibility of stripping. He was not allowed to sell the fish he caught, so even the possibility of a little surreptitious gain or profit through stripping is excluded. And as the officer was unaware of the purpose of the returns he made, he cannot be accused of "cooking" them to produce any desired result.

So much, then, for the "widespread occurrence" of stripping of berried lobsters in the Lancashire and Western District.

L.M.B.C. MEMOIRS.

No. XX. BUCCINUM.

(THE WHELK)

BY

WM. J. DAKIN, D.Sc., F.L.S.

CLASSIFICATION.

The whelk belongs to that class of the cephaloporous Mollusca, the GASTROPODA, which includes also the limpets, land snails, and nudibranchs. The group is characterised by the possession of an asymmetrical body, a well developed head bearing eyes and tentacles, a foot for creeping, and a shell consisting of one piece only (univalve). In some cases the shell is reduced considerably, and it may even disappear completely in the adult (e.g. Nudibranchiata).

The Gastropoda may be conveniently divided into the two sub-classes:—STREPTONEURA and EUTHYNEURA. The first of these groups is defined by the nervous system being involved in the torsion of the body so that the visceral loop joining the visceral and pleural ganglia is twisted into a figure of eight. The morphological right side of the loop becomes carried over the alimentary canal to the topographical left side, and the left half, under, to the right side. This sub-class is also named Prosobranchia from the fact that, in most genera, the gills lie anterior to the heart.

The whelk is a representative of the Streptoneura, and the common land snail is a type of the other group, Euthyneura; the exact position of *Buccinum* can be seen in the scheme given on the next page.

CLASS GASTROPODA.

Body asymmetrical, well developed head, well developed foot, usually with flat creeping sole. Shell in one piece, usually coiled in a spiral, but may be reduced and completely disappear. Pallial complex situated on the right or left side in a more or less anterior position. One half, usually the morphological left, of the pallial complex reduced, and may be absent.

SUB-CLASS I. Streptoneura (=Prosobranchia).

Sexes separate. Visceral loop twisted into figure of eight. Pallial complex placed anteriorly. In most, only one gill, which is situated in front of heart. Chiefly marine. Shell very rarely absent.

Order I. Diotocardia (=Aspidobranchia).

Order II. Monotocardia (=Pectinibranchia).

Heart with one auricle. One gill with leaflets on one side of an axis. Well differentiated osphradium. Eye a closed vesicle. Single kidney. Siphon and penis usually present.

Sub-order I. Architaenioglossa.

Sub-order II. Taenioglossa.

Sub-order III. Stenoglossa.

Pectinibranchs with much concentrated nervous system. Proboscis, siphon, and penis always present.

Tribe I. Rachiglossa.

Radular formula. I.I.I.

Fam. Buccinidae

Gen. *Buccinum*.

GENERAL DESCRIPTION.

The body of the whelk is divisible into three obvious external regions, head, foot, and visceral mass (Pl. I, fig. 7). A large part of the animal can be extended beyond the mouth of the shell, but the visceral mass always remains hidden, and the entire animal can be retracted when disturbed. The integument of the visceral mass is produced to form that characteristic molluscan structure—the mantle (Pl. I, fig. 7, *Pall.*). The mantle forms a continuous cloak round the body, its free edge being just visible at the shell mouth when the animal is extended. It encloses a space, the mantle cavity, which is best developed on the dorsal and anterior surface. The shell is secreted chiefly by the epithelium of the mantle, particularly of the mantle edge. The organs in the mantle cavity will be referred to later.

The head of the whelk in an extended condition bears anteriorly two appendages, the tentacles (fig. 7, *Tent.*). These are compressed dorsoventrally at their base but are produced to a fine conical lip. They are capable of considerable extension and contraction, but cannot be introverted. At the base of the tentacles and on their outer sides are a pair of cephalic eyes, situated on slight lateral prominences.*

Below the tentacles and in the middle line is a conspicuous opening, an apparent mouth. This is, however, not the true entrance to the buccal cavity. The latter opens at the extremity of a retractile snout but has been carried backwards, owing to an ingrowth of integument, and consequently the true mouth is only seen when

* One specimen of *Buccinum undatum* found at Port Erin possessed three tentacles—perfectly normal in shape and each with an eye at the base. From the position it is probable that a second tentacle and eye was present on the left side. A similar case in *Patella vulgata* has been recorded by Bateson.

the invaginated tube is everted. This eversible tube is the proboscis, and it can be extended about two inches outside the opening of the apparent mouth.

The Foot forms the greater part of the mass seen when the animal is fully extended (Pl. I, fig. 7). It has a very different appearance in life from that seen even in the best preserved dead specimens, where the foot is hard and always somewhat contracted. It is formed of a complex and powerful mass of muscles, and when fully extended is perfectly smooth, without any trace of wrinkles, soft and velvety to the touch, and capable of much change of shape. It has a perfectly flat ventral surface, with a blunt anterior and a tapering posterior end (Pl. II, fig. 9). The ventral surface or sole is used for creeping, but I have also seen the anterior part used for holding food matters. When a whelk supports itself above the water-line in an aquarium tank, it does so solely by means of suction. Some little force is required to detach it, but the sole is simply slimy and no adhesive substance is secreted.

Upon the dorsal but posterior region of the foot is situated a horny disc, the operculum, used for closing the aperture of the shell when the animal is withdrawn.

Running transversely across the anterior part of the foot is the deep pedal groove. This will be described in detail below, in the section on the foot.

THE SHELL.

The shell of the whelk (Pl. I, figs. 1 and 2), secreted by the mantle, consists of a single valve which is coiled spirally owing to the varying conditions under which different parts of the mantle edge secrete shell substance. In most cases the twist is of such a nature that if the shell is held by the apex with the aperture away from the observer and turned down-

wards, the aperture will lie to the right of the columella. Shells coiled in this manner are “dextral,” but one occasionally finds a “sinistral” whelk with the spiral reversed and the asymmetrical viscera developed on the opposite side of the body.

The shell may be regarded as a long cone coiled into a spiral. Text-fig. 1 shows the terms in use for the

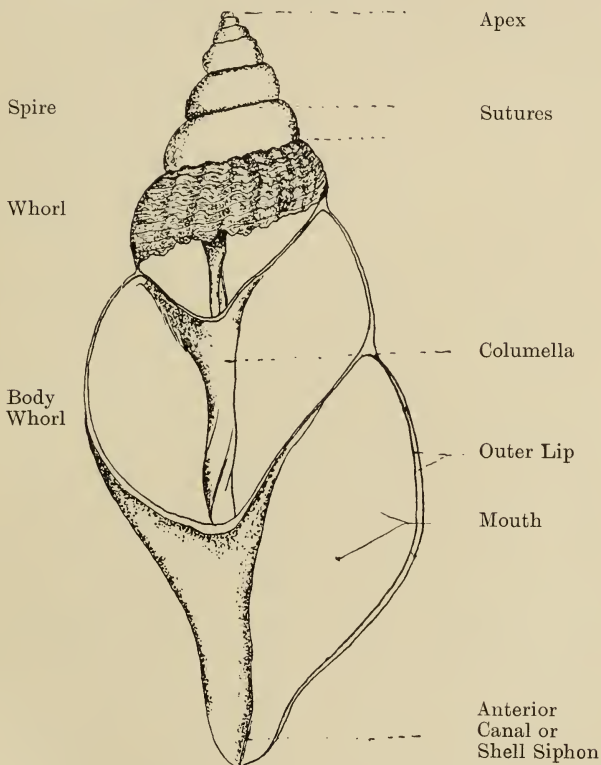


FIG. 1.

different parts. The **apex** is the oldest part of the shell and often in gastropods presents important characters, such as being coiled in the reverse direction.

The **whorls** are in close contact and are about six or

seven in number in an average adult specimen. The last turn of the shell is known as the **body whorl** and is extremely large. The successive whorls of the shell in the female show a greater enlargement than is the case in male shells. The lines marking the point of contact of two successive whorls are known as the sutures. The mouth of the shell is produced into a short anterior canal or shell siphon (fig. 1, Pl. I) in which lies a prolongation of the mantle, the pallial siphon (fig. 7, *Siph.*). This condition is characteristic of carnivorous gastropods. The pallial siphon can be extended some distance out of the shelly canal, into which it is retracted when the body is withdrawn. In some gastropods there is also an anal or posterior canal which is represented by the perforation in *Fissurella* and the series of holes in *Haliotis*.

The outer surface of the shell is covered by a horny layer which can be stripped off quite easily. In worn specimens it is frequently absent in patches. This layer, the periostracum (Pl. I, fig. 4) gives the shell a somewhat brown appearance and a furry surface. It will be referred to in detail below. The external surface of the whorls is marked by very distinct grooves and ridges which run regularly in a longitudinal direction, and can be traced round all the whorls to the apex of the shell. They correspond to the lines radiating from the umbo of a lamellibranch shell. In *Buccinum* these lines are arranged on crests and troughs; and are in groups of about six ridges between two crests. The crests become much more distinct as one passes from the mouth towards the apex of the shell, where they are more crowded.

Running roughly at right angles to the former system of longitudinal crests, and therefore transversely to the direction of growth, is another system. This is made up of two sets of markings—lines of growth and

broad waves or corrugations. The lines of growth are rather indefinite striae, not nearly so distinct as the ridges of the first system, except near the mouth of the shell and particularly on the shell siphon. The corrugations on the other hand are much more definite on the earlier whorls, and on the last or mouth whorl of an adult shell they are only well marked near the suture line.

These transverse corrugations relieve the monotony of the plane surface and are one of the first characters which strike the observer when comparing the shell with that of *Fusus*.

A longitudinal section taken through the body whorl of the shell shows the following structure:—(a) an outer wide layer of irregular columns; (b) a middle and narrower layer, also composed of columns, which are, however, regular in shape and arranged at almost a right angle to the surface of the shell; (c) an inner layer characterised by delicate oblique cross lines.

The outermost layer begins at the outer lips of the shell mouth, the middle layer commences a little further inside, and it is soon followed by the inner layer. According to Tullberg, who seems to have made a careful study of the structure, a fourth and more internal layer still, occurs in the older whorls and increases in thickness as one approaches the apex of the shell. This is not seen in the micro-photograph, which is from a section through the wall of the body whorl. Text-fig. 2, after Tullberg, indicates the position of origin of the layers.

In addition to these layers of shell substance, there is a very well developed periostracum which can be quite easily peeled off from the shell and examined without sectioning.

The Periostracum is a chitinous layer, yellow in colour, and raised on the external surface into a number

of papillae which give the shell the appearance of being covered with a velvety tissue. These papillae are all directed backwards towards the apex of the shell. In sections (Text-fig. 2) the periostracum appears to be made up of layers lying obliquely to the surface. A spine is simply a prolongation of one of these layers.

The outer layer (*a*) of shell (Text-fig. 2, *a*) is marked by the possession of more organic substance than the other layers. The calcareous substance crystallises irregularly as mentioned above, and the appearance can be understood better perhaps from the photograph (Pl. I, fig. 6) than from any description.

The middle layer, Text-fig. 2 (*b*), is, as we have seen above, marked in longitudinal sections by parallel lines running perpendicular to the surface of the shell. In transverse sections, however, the appearance of this layer

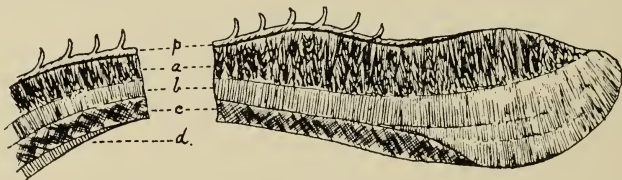


FIG. 2.

is, as Tullberg remarked, just like the inner layer (*c*) in longitudinal section. This structure will be understood better when the remaining two layers (*c* and *d*) inside it are examined in transverse section. It will then be seen that the layer (*d*) is marked like the middle layer (*b*), and thus both (*b*) and (*d*) seem built of parallel columns in longitudinal sections, whilst they are marked by oblique lines in transverse section. The layer (*c*) is apparently built up of parallel columns in transverse section. The reason for this strange appearance is that the three inner layers (*b*, *c*, and *d*) are built up in exactly the same way

of small plates which are arranged in rows with the plates at an angle to each other. Whilst, however, the rows of the layers (*b* and *d*) are situated in a line at right angles to the direction of the whorls, the other layer has the rows running almost in the direction of the lines of growth. It follows that in a longitudinal section of the shell, the plates of layers (*b* and *d*) are seen from their cut faces and appear as columns, the cross striation marking the cut faces of the plate. The plates of layer (*c*) are, however, cut so that they are seen in side view, and the oblique running lines mark the edges of the plates. We might therefore divide the shell into two layers, an outer and an inner, the latter with three subsidiary strata built up in the same way, but, as the geologists would say, unconformable. We have already seen that at the apex of the shell there are a number of partitions cutting off small chambers. These are formed entirely by layer (*d*) of the shell.

Formation of the shell layers and periostracum.—The shell is formed by the entire surface of the mantle, but chiefly by the mantle edge. The periostracum and the three outer shell layers are formed solely by the edge, each of them farther from the actual margin, whilst the innermost layer (*a*) can be increased in thickness throughout life by the mantle immediately below it. The structure of the mantle edge, with the shell secreting cells, will be given in the section on the mantle.

There is probably little doubt that the actual crystallisation of the shell substance into the structure seen in sections takes place outside the secreting cells, and is determined to a certain extent by the constitution—a mixture of conchiolin and lime—of the secretion. The origin of the complex shell structures must, however, be

further governed by an architecture already present in the secreting area of the mantle. Such a differentiation of the secreting cells is, however, ultra-microscopic, and the sculpture of a mollusc shell belongs to the same category as the regular shape of the teeth on the radula, the form of placoid scales and the growth of the Echinus plates.

The Columellar muscle is attached to the shell by the same kind of cells that are noticed in *Pecten* and other lamellibranchs. During life a movement of the muscle takes place, but there is no actual movement of the muscle fibres. A growth of new fibres takes place in front, and resorption behind, so that as a result the whole structure appears to move forwards.

THE FOOT.

The ventral creeping foot is exceedingly well developed in *Buccinum*. It is muscular, and capable of very considerable expansion and contraction, so that whilst soft and almost translucent when expanded, it becomes opaque and tough as cartilage and difficult to deal with in dissections when contracted. The flat and smooth ventral surface, or sole, has, when the foot is expanded the shape indicated in fig. 9, Pl. II. Thus the anterior margin of the foot is broad, and the width remains constant for some distance backwards until towards the posterior end it gradually narrows away to a point. Running parallel to the anterior margin of the foot is a deep groove (fig. 9, Pl. II, *Ped. gl.*), which cuts off an anterior narrow ridge from the major portion of the foot; and into this anterior groove open numerous glands. The molluscan foot is usually well provided with glands, and these may be divided into (*a*) scattered gland cells covering the foot, and (*b*) specialised compound glands.

The latter class includes the byssus gland of the lamelli-branchiata. In the gastropoda the specialised glands may be divided into an anterior foot gland, often opening anteriorly into a transverse groove, and an unpaired median gland opening into a cavity situated in the middle line of the foot. It is very probable, however, that both these are parts of the same system, and it is generally believed that one or other is homologous to the byssus gland of the lamellibranchs. The median unpaired opening is absent in the whelk, but the anterior glands are very well developed, and the pedal groove can be observed quite early in the embryo. The portion of the foot anterior and dorsal to the pedal groove, as well as the anterior part of the ventral surface, may be used as a clasping organ, and in this way the whelk can to a certain extent retain its hold whilst using the proboscis and radular apparatus to bore through a molluscan shell or a crustacean exoskeleton.

As stated above, the foot is highly muscular. It is almost entirely composed of muscle fibres, and moreover the greater part of it is one muscle—the columellar muscle of the shell, which arises from the columella (Pl. I, fig. 3), and in average-sized specimens from the inner surface of the 5th whorl, and is inserted into the under surface of the operculum, and thus must pass through the foot in order to reach this point. In the foot it is crescentic in section, the convex side being dorsal and very distinctly marked off from the narrow band of more superficial tissue. The whole muscle lies here near to the dorsal surface of the foot. The attachment to the operculum is on the ventral side and forms an elliptical area which is situated eccentrically.

The columellar muscle of the gastropods has been homologised with the adductor of the lamellibranchs by

those authors who have considered the operculum homologous with the other valve of the lamellibranch shell; and with the retractor muscles of the foot, by those who consider the operculum as representing the byssus of the lamellibranchs. Both theories are untenable. The operculum is probably a new structure, and the search for homologies is sometimes carried too far.

The foot exhibits very great changes in size, according to whether it is fully expanded or completely contracted. Whilst the whelk is creeping about, the foot is almost constantly changing in shape, and if not in total volume the size of different regions at least varies. This power of change is due to the vascular supply and the muscular structure. The pedal arteries form a very complete network extending throughout the foot. Blood runs back through a large central sinus. The expansion takes place through the forcible intrusion of blood into the foot. If the foot of an expanded animal be suddenly cut off with a very sharp scalpel, the sudden outflow, or jet of blood, seen as one severs the sinus, is most striking. This is due to the muscular contraction which begins immediately the foot is touched with the knife. The blood, in fact, has most important functions to perform in effecting both the expansion of the foot and the extrusion of the proboscis.

The creeping action of the gastropod foot has already attracted considerable attention. In most cases when the animal is in motion a series of waves can be seen coursing along the foot. These may be in a direction from behind forwards—*direct* (*Aplysia*, *Doris*, etc.), or in the reverse direction anterior to posterior—*retrograde* (*Littorina littorea* and others). In some gastropods again the foot is divided into two longitudinal halves and these move alternately, both exhibiting systems of waves. In

addition to the above types there are cases (Parker) where there seem to be no waves at all and the foot glides like a Planarian over the substratum. In *Buccinum* the waves can only be detected at the edges of the foot, but in addition to this motion the whole of the anterior part can be moved forward and then attached whilst the posterior portion is pulled up to it. This is particularly well seen when the mollusc is removed from the water. The actual forward motion of the foot is caused by muscular contraction pulling forwards all those regions of the foot temporarily raised,—at least when compared with the rest of the foot. These regions are the waves, the crests being for the time the fixed portions.

The Operculum is a disc of chitin with a deposit of calcium carbonate, placed on the dorsal surface of the posterior part of the foot (Pl. I, fig. 7, *Op.*, and fig. 5). It is carried on a slight elevation, the “opercular disc,” and when the animal is withdrawn into the shell fits into the mouth, closing the orifice completely. The operculum is pulled to with considerable force, for, since the columellar muscle is attached to this plate and the direction of pull is almost exactly along the muscle, the whole force of which the muscle is capable can be exerted. The amount of lime in the operculum of *Buccinum* is but small, and the structure is horny in appearance, lacking the strength of some other gastropod opercula which may be thick and extremely hard.

Seen from its superior surface, it is marked by very distinct lines of growth which are arranged concentrically round an eccentrically placed “marginal nucleus.” The attachment to the foot is also eccentric, the oval area lying quite to one side, the side further from the nucleus and anterior when the foot is uncontracted. Round the area of attachment the tissue of the opercular disc form

a collar which projects for a little distance, sheathing the unattached marginal regions of the operculum. This "opercular lip" is deepest on the posterior border where there is a greater width of unattached operculum. When creeping, the operculum is arranged, as we have seen, transversely across the foot. The anterior margin in this position is the *internal* border, the posterior margin the *external* border when the operculum is applied to the shell mouth.

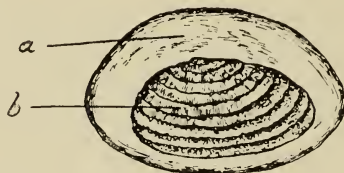


FIG. 2a.

If the operculum is removed from the foot and the attached or ventral surface examined, a very different system of striae will be seen. The operculum is, as a matter of fact, composed of several layers, and the markings on the superior and inferior surfaces are therefore quite independent of one another. The area of attachment, as already mentioned, is situated towards the anterior margin, and entirely to one side, therefore, of the nucleus. This area is marked by about ten bands (in adult specimens), arranged concentrically, but with only part of any band showing, the remainder being outside the area of attachment. Furthermore, these bands are arranged in an imbricating manner (Text-fig. 2a, *b*), each one nearer to the centre overlapping its more marginal neighbour. The area outside the region of attachment is covered with a somewhat glossy horny layer, which hides the concentric bands

as stated above. This glossy ventral layer is broadest under the posterior margin (Text-fig. 2a, *a*). The operculum is composed of three layers, a very delicate superior layer, a median layer of considerable thickness which is itself formed of numerous laminae arranged at an acute angle to the plane of the operculum, and a third and most ventral layer, the glossy one described above. The thin superior layer is formed by a pad of cells situated in a cleft *below* the anterior lip of the opercular disc. The middle layer is secreted by the cells of the disc at the margin of the region of attachment, and chiefly anteriorly. As a matter of fact, the epithelium of the foot is perfectly continuous underneath the operculum, and it is by means of these cells that the muscle fibres are attached to the operculum. The most ventral layer of all is produced by the cells of the opercular lip. It will be noticed that this lip is much deeper and more obvious altogether posteriorly where the glossy layer is widest and best developed.

It is possible without more than decalcification to cut sections through foot and operculum. These will show quite easily the positions of the various secreting cells. The secreting cells are characterised by their great depth. They are narrow and about four times as deep as the other epithelial cells of the foot in the vicinity.

The pedal groove (Pl. II, fig. 9, *Ped. gl.*; fig. 10, *Ped. gr.*) is a deep incision running transversely across the anterior margin of the foot. It appears quite early in the larva, and is relatively very large at this period. In transverse sections of the groove (Pl. II, fig. 10), or longitudinal sections of the foot, a region round the base of the groove can be seen with the unaided eye to be different from the rest of the foot. Sections stained with methyl-blue-eosin are very characteristic and make

obvious the fact that this peculiar region is composed of numerous compound glands.

The groove is, in fact, nothing but a slit-like common opening of a very large number of glands. The foot in the region of the groove is bounded, as elsewhere, by a layer of deep epithelial cells with characteristic striated cuticular margin and cilia. These ciliated cells are compressed laterally and separated by gland cells. Exactly the same type of cell lines the groove, and there is no change even at the bottom of it, except that the cilia are longer and much better developed than elsewhere. Here the epithelial cells are much compressed and the nuclei are drawn out into long spindles.

Between the cells open the compound glands. Below the epithelium is the muscular tissue, built up mainly of transverse running fibres, so that their cut ends appear in section (fig. 10, *Ped. mus.*). There are, however, scattered oblique and longitudinal fibres. In the region of the groove the muscular tissue remains absent, and its place is taken by the glands. Thus the very distinct demarcation of the gland is due as much to the absence of muscles here as to the presence of the gland cells. The glandular tissue (fig. 10, *Ped. gl.*) is very characteristic. There is no blue staining contents characteristic of the mucous gland cells or similar cells in the mantle and pedal epithelium. Instead, there are packets of very thin-walled cells situated some considerable distance below the epithelium.

The packets are bounded by very thin connective tissue sheaths, but this is so delicate that it may seem no more than the outer walls of the cells which are arranged to form the packet.

The cells are intensely vacuolated. From each packet a narrow path of the same cells runs to the

epithelium. These cells, however, do not enclose any canal. It appears as if the secretion must reach the groove by passing through the cells. Usually in sections there are no traces of secretion in the groove, and in living specimens no mucus or other fluid appears coming from the groove. What is, then, the function of the gland? It is homologous with the pedal pore of many other gastropoda; once considered an aquiferous pore by which water entered the animal. The gland secretes the substance of which the egg capsules are formed. This fact, noted in 1899 by Cunningham to apply to *Buccinum* and *Murex*, has since been found to be true for *Purpura* by Pelseneer.

THE MANTLE AND PALLIAL CAVITY.

The pallial cavity proper is the space between the mantle and the dorsal surface of the body of the animal. Its floor is formed by the body wall, its roof by the mantle. It will be advisable to refer in a general way to this part of the animal in a separate short section, inasmuch as the cavity contains several important organs belonging to different systems.

These organs considered together may be termed the Organs of the Pallial Complex. Three of them are structures developed largely from the mantle itself—the ctenidium or gill, the osphradium, and the mucous gland (Pl. II, fig. 8). Furthermore, there are to be considered the Rectum and Anal opening (fig. 8, *Rect.*), the Renal opening, and the male and female genital openings. The mantle itself is thick and muscular, and this applies most markedly to the free edge. The edge is slightly recurved outwards, and just behind the extreme margin and on the outer surface is a delicate band of yellow pigment.

If the mantle is slit down the extreme right side on the *left* of the rectum (and the oviduct in the female),

and turned over to the left, the organs of the pallial cavity can be easily made out. On the extreme left, and arising from the inner surface of the mantle, are two ridges which form the side walls of a groove, the pallial siphon (fig. 8, *Siph.*). These side walls and the basal part of the groove are continued so as to form a truncated cone with a gutter down one side of it. This pallial siphon lies in the shell siphon, but can be extended a considerable distance when the animal is active. Water entering the mantle cavity passes in by means of this tube, which is characteristic of the carnivorous gastropods. One would imagine from observation of the living animal that the siphon was connected with some important system of sense organs. It is continually in motion from side to side, and extends much further from the animal and is more active than the tentacles.

Examination of the mantle cavity in this light reveals an interesting series of organs. The osphradium, which is a darkly pigmented structure on the left side, is situated right across the end of the siphon (fig. 8, *Osph.*). Thus all water entering the pallial cavity must pass over it *before reaching the other organs.*

The osphradium is a narrow organ composed of two series of leaflets arranged along the sides of a central axis. It will be discussed further in the chapter on the sense organs. To the right of the osphradium is the gill (fig. 8, *Ct.*). It is separated from the osphradium by the ctenidial axis which can be seen as a white ridge running from the most distal part of the gill to the inner end of the pallial cavity. The gill itself is composed of leaflets arranged on one side of this axis only, the topographical right. Between the ctenidium and the cut side of the mantle the inner surface of the latter is occupied by the large mucous or Hypobranchial gland (fig. 8, *Mu. gl.*),

which extends therefore from gill to rectum. The gland is made up of a number of deep lamellar foldings of the mantle, about twenty in number. The structure of this organ is considered elsewhere.

The Anus (fig. 8) is situated at the apex of a prominent papilla on the right side (topographical).

The vaginal portion of the oviduct is conspicuous in ripe females as an opaque white cylinder on the extreme right. Its opening into the pallial cavity is not so prominent as the anal opening by reason of the lowness of the papilla. In male specimens the pallial cavity will be filled by the large penis which usually lies twisted backwards. All these organs terminate about the same distance from the mantle edge and thus leave free a wide region, the inner surface of the thickened margin.

The Renal opening is a slit-like pore, situated to the left of, and slightly above the rectum on the posterior wall of the mantle cavity, in fact on the membrane separating this cavity from the renal organ. The long axis of the slit is dorso-ventral in direction.

T h e M a n t l e E d g e .

A great part of the mantle, whether at the thickened edge or in the region of the ctenidium and other organs of the pallial complex, is composed of a modified connective tissue. One sees in sections practically nothing but thin cell walls with nuclei adhering to them, and here and there fragments of muscle fibres. This characteristic mantle connective tissue (figs. 31, *x con.* and 45, *Pall. gl.*) is seen very well in the thickened edge, where it occupies about $\frac{2}{3}$ of the total thickness. Against the epithelial layer, which bounds the surface of the mantle, and underlying this everywhere, is a thick sheet of compact fibrillar connective tissue of the more normal

invertebrate type (fig. 45). Running through this layer are muscle fibres of which the circular are near to the surface whilst longitudinal fibres occur more frequently nearer the central connective tissue mass. The most important feature of the mantle edge is the epithelium, for this is concerned here with shell building. The epithelium covering the free inner surface of the mantle is formed of columnar cells whose height is several times their breadth. These cells are typical ciliated cells, so that the epithelium presents here a ciliated surface. The ciliated cells are separated everywhere by mucous cells. These ciliated cells extend round the edge of the mantle to the shell side. On this side of the mantle (and in that region where the mantle forms the roof of the pallial cavity) there is a remarkable gland running across and opening to the surface not far from the mantle edge. The gland is situated deep below the epithelium imbedded in connective tissue. The actual gland cells communicate with the surface by long processes which are so crowded together that, just below the epithelium and away from the gland cells, they appear like the fibres of a broad nerve. The resemblance is quite striking in methyl-blue-eosin stained sections, for the stain is not unlike a nerve stain. Another very striking feature of the gland is that, instead of the fibre-like communication to the surface opening between epithelial cells, the epithelium appears to be absent for a short space and its place taken, in fact, by the gland cell processes themselves.

This glandular mass in the *Buccinum* mantle was noticed by Tullberg, who discusses its function without, however, coming to any definite conclusion. He states that it might very well be a gland for the secretion of the Periostracum, and this is supported by the fact that the gland is absent on the mantle below the visceral mass

where no Periostracum is formed. Against this, however, he adds that the gland is too large for this function alone and that it would be peculiar to find a special gland for the secretion of the Periostracum, whilst the shell itself is formed by the general epithelium of the mantle.

In my opinion the objections that Tullberg brought forward are not important. In the lamellibranchs the Periostracum arises in a groove from a very definite pad of cells, certainly epithelial in position but still differentiated enough to form a special organ. Hence there is no reason why the thick Periostracum of the whelk should not be formed by this gland. In any case no other function has been ascribed to it. The comparative anatomy of this organ is being followed up by the author.

The shell side of the mantle from the opening of the gland inwards is faced by epithelial cells differing from those already noted in the absence of cilia. These are the shell secreting cells. They are marked, particularly near the gland, by the possession of granules of yellow pigment.

RESPIRATORY ORGAN (CTENIDIUM).

There is only one ctenidium present in *Buccinum*, as in most of the higher Gastropoda. This is the morphological right gill, but is situated now on the left side of the pallial cavity. It has already been referred to as being visible through the thickness of the mantle. This ctenidium extends from a point, in line with the anterior limits of the osphradium and mucous gland, as far back as the pericardium (fig. 8, *Ct.*). It is composed of a large number of flattened leaflets which are packed parallel to one another and vary in size, so that they become

successively smaller as either end of the ctenidium is approached.

These leaflets are roughly triangular in shape. The axis of the ctenidium lies close to the osphradium (fig. 8, *Ct. ax.*). The respiratory leaflets are disposed along one side only and are further attached by the whole of their bases to the mantle (see Text-fig. 3, p. 277).

The ctenidium is therefore *Monopectinate*.

The efferent branchial vessel runs along under the ctenidial axis and thus the area of each leaflet adjoining the axis may be known as the efferent end and the free side, the efferent margin of each leaflet. Branchial lacunae extend up the afferent margins of the leaflets from the afferent branchial sinus which lies in the mantle immediately below the point of attachment of the afferent edges of the lamellae.

The ctenidial axis (fig. 8, *Ct. ax.*) is conspicuous as a smooth ridge running along the inner surface of the mantle as far as there are ctenidial leaflets.

It is made of the same peculiarly vacuolated connective tissue (fig. 39, *Ct. gl.*) seen in the mantle at the base of the ctenidial leaflets. Towards the side to which the branchial lamellae are attached the place of this tissue is taken by longitudinal muscle fibres (fig. 39, *Ct. mus.*). This layer increases in thickness towards the middle of the ridge.

The ctenidial nerve (fig. 39, *Ct. n.*) runs along the axis not far from the osphradial side, and gives off branches at intervals, which pass to the leaflets.

HISTOLOGY.

The microscopic structure of the ctenidial leaflets is interesting by reason of the histological differentiation of the different areas. Each leaflet consists of a double

bounding layer of epithelium enclosing a flattened cavity, which is a blood space. Underlying this epithelial layer (figs. 31, 32, 33, *ct. e.'*, *ct. e''*, *ct. e'''*) there is an internal connective tissue layer with muscles, lining the blood space just mentioned. Between these two layers a supporting tissue is developed which is much thickened near the ctenidial axis and runs along the efferent margin of each leaflet (figs. 31, 32, 33, *Sup. m.*).

This supporting tissue, which in its thickened parts is apparently hyaline, has been regarded as cartilaginous or chitinous; this will be referred to below.

The relation of the various structures enumerated can be made out best in a section transverse to the leaflets and perpendicular to the mantle. Such a section, running through the efferent margin, is figured on Pl. IV (figs. 31, 32, 33).

The external epithelium, which bounds the lamellae, differs considerably in the various regions. Taking the section through a point near the efferent margin, there is first the free edge to be considered. The epithelium here is composed of somewhat deep and regular columnal cells bearing cilia (fig. 33, *ct. e.'*). This epithelium diminishes in thickness and becomes more irregular than indicated in the figure as one leaves the free margin. The cilia are also lost and the cells appear glandular (fig. 33.) Following on this region the cells again become more deep, more regular and with deeply staining cytoplasm. They all bear well developed cilia, so that the whole area occupied (fig. 32, *Ct. e'''*) by them is very conspicuous by reason of the marked contrast with the glandular cells lacking cilia on either side of it. Passing this area towards the mantle, the cells become once more glandular and without cilia. The epithelium here is often thrown into folds through contraction, probably on

fixation (fig. 31, *Ct. e.*"), but this in all probability can take place in life since there is a plentiful supply of muscles in the sub-epithelial layers.

Immediately under the epithelium there is a supporting membrane. This is very delicate and almost indistinguishable under the greater part of the area of the leaflets, but thickens considerably, so that it becomes the outstanding feature in stained sections, near the efferent margin (fig. 33, *Sup. m.*). It is this substance that has been termed cartilage or chitin. It is clear, however, that this supporting membrane must be considered in conjunction with the connective tissue on its internal face, that is, bounding the blood cavity. This layer is distinctly peculiar. Seen in transverse sections, all that can be observed are a few nuclei with very little surrounding cytoplasm (fig. 32, *Ct. con.*). If, however, a section is cut very slightly tangential to the leaflet, it may be possible to secure the layer itself. It then appears made up of squamous cells, often with the corners drawn out (fig. 34). If these cells touched, making up a definite membrane, it would be difficult to distinguish them from an endothelium. Instead of this, they are more or less scattered, and at odd places there is a crowding together to form islands of pseudo membrane. This tissue is thus very characteristic. Now the supporting membrane is in close contact with these cells, and moreover, in places it is quite continuous with the matrix surrounding them. This brings out strongly its resemblance to the matrix of ordinary connective tissue both in structure and in staining. Hence I have come to the conclusion that the supporting structure, thickened at the efferent margin, is really a connective tissue, free from cells or fibres, and that the cells which have formed it occur on its inner surface.

The relative areas covered by the different structures are indicated in Text-fig. 3.

The connective tissue supporting skeleton extends from the axis along the efferent border to the angle. At first it extends from the free edge of each leaflet to the mantle, but it gradually becomes reduced. The area of ciliated cells increases quickly and then extends to the angle of efferent and afferent edges, occupying in sections from about a third to one-sixth of the length of the leaflet (measured from efferent margin to mantle side). The glandular cell area is nearest to the mantle. It increases steadily in thickness as the afferent edge of the leaflet is approached and is widest in that region.

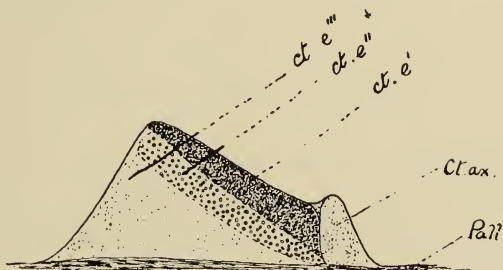


FIG. 3. *ct. e'''* Area of Glandular Cells. *ct. e''* Area of Ciliated Cells. These differ from the reference letters on Plate IV.

One further detail remains to be described. Peculiar characteristic bridges run across the blood cavity in the leaflet. Each of these appears to be formed of muscle fibrils which diverge at their extremities (fig. 34, *Ct. mus.*). The cell in which these muscular fibrillae have been formed remains, and is usually quite obvious with its residual cytoplasm and nucleus in the centre of the bridge.

Thus it is possible by contraction of these numerous muscle strands to approximate the two surfaces of the leaflets, and hence to force out the contained blood.

Another peculiar histological structure may be referred to here. The epithelium of the lamellae is simply the folded epithelium of the inner surface of the mantle. The outer epithelium bounding the mantle externally is, of course, not folded here or elsewhere (fig. 31, *Pall. ep.*). Between these two layers there is the very characteristic median stratum of connective tissue made up of extremely large cells with delicate walls, feebly staining nuclei and practically no contents (fig. 31, *X. con.*). What function this layer may play has so far not suggested itself.

MUCOUS GLAND.

The mucous gland is the most conspicuous organ in the pallial cavity, both by reason of its secretion as well as by its structure. It is a modified region of the mantle between the ctenidium and the rectum where gland cells predominate, and the inner wall of the mantle is thrown into deep folds which run transversely, overlapping slightly and hanging down into the pallial cavity.

The mucous gland is really the inner wall of the mantle whose cells are elongated and specialised as gland cells. The anterior folds of the gland are directed backwards, the most posterior ones forward (fig. 8, *Mu. gl.*). They are much thicker than the ctenidial leaflets and are separated by much greater spaces. The number varies, 20-25 being about an average for a full-sized whelk.

This region of the mantle is extremely well supplied with blood, as a glance at fig. 35 will show, and numerous vessels run down parallel to the folds from the reno-mucous vessel to the afferent branchial vessel. The secretion of the gland is either perfectly hyaline or yellow-white in colour. It is perfectly abominable to handle, and after months in

five per cent. formalin it still retains its fresh appearance and consistency. It can be drawn out into long threads of surprising length (some feet) without breaking. The secretion of this matter takes place very rapidly when the animal is severely stimulated, particularly with irritating fluids. Concerning its function but little is known. It would appear in the first place to be a protective—or defensive—secretion. It does not leave the animal gradually after secretion but is produced, as we have seen, spasmodically and quickly, and raises itself in a sheet. Obviously it removes in this way any dirt, sand grains or other matter from the organs of the pallial cavity, and, moreover, protects them to a certain extent from the entrance of such materials.

HISTOLOGY OF MUCOUS GLAND.

Sections taken through the mucous gland show that we have to deal with a very much modified epithelial layer, which rests on a basement membrane of connective tissue overlying the peculiar cellular connective tissue of the mantle (fig. 40, *Con.*). This latter tissue extends into the folds, but only occurs as bridges running across at intervals and leaving great cavities between the two sheets of epithelium. The epithelium is composed of three types of cells as described by Bernard: 1, Mucous cells; 2, ciliated cells; 3, neuro-epithelial cells.

In sections, the characteristic appearance is to find cell walls running from the periphery to the basement membrane dividing the whole up into large chambers filled with mucus (fig. 40, *Mu. c.*), but in addition there is a more protoplasmic peripheral region bearing cilia and another series of cell walls. There are also two distinct nuclear regions, one of which is peripheral

(nuclei belonging to the ciliated cells), and the other basal (nuclei of the mucous cells).

The ciliated cells are long and narrow, with, however, an expansion at the periphery which forms a kind of platform. The mucous cells are very large and wide, their length varies according to the amount of mucus present. Their peripheral ends are, however, often quite attenuated.

Bernard has made a very detailed study of the process of mucus formation, examining pieces of living tissue from the gland with the microscope. He concludes that before the production of mucus the ciliated cells are all in contact and form a continuous surface without grooves or openings. The mucous cells do not reach at first the level of the surface, but gradually they extend until they appear between the ciliated cells. A small opening occurs and from it the excretion pours out as a drop. The cell continues to secrete mucus.

The ciliated cells can detach their peripheral portions, which go off as ciliated spherules minus nucleus and with little protoplasm. Finally dead cells of both kinds are expelled and may be seen in the excretion.

THE ALIMENTARY CANAL.

The alimentary canal opens at the true mouth, at the apex of a long retractile proboscis (fig. 11, *Prob.*), probably not to be seen without dissection in the preserved specimens. The opening which has been noted on the surface of the head below the tentacles is not then the true mouth. At this point the body wall is turned in to form a permanent introvert of considerable length, part of which, however, is again turned on itself to form

The Proboscis. Text-fig. 4 explains this part of the

body better than any description. The invaginated body wall between *a* and *d* forms both the proboscis, which can be protruded, and a proboscis sheath; part of the latter, however, can be everted (fig. *b* to *c*).

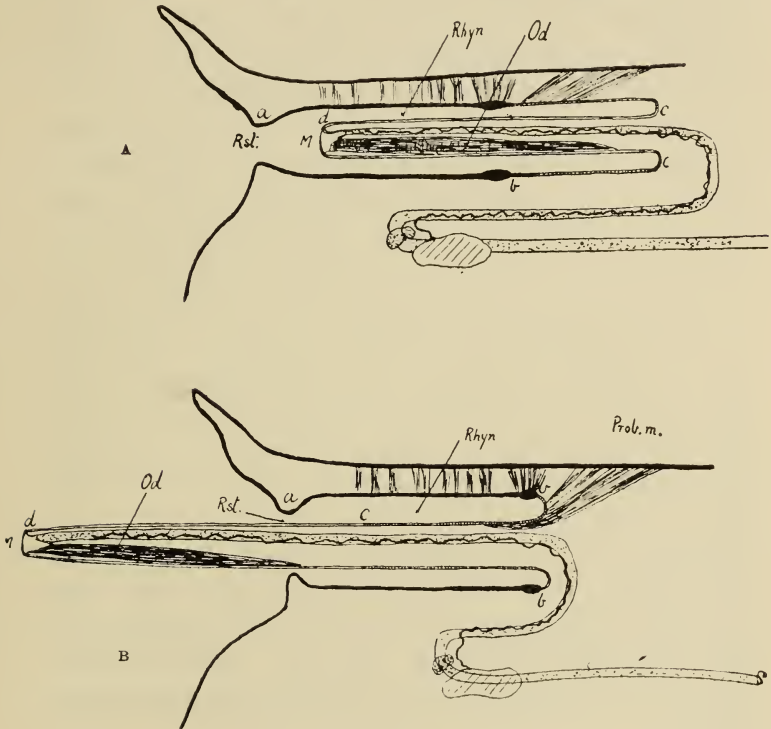


FIG. 4.

The section of the proboscis sheath *a-b* in Text-fig. 4 is connected somewhat closely to the body wall by short muscles. This region retains its position whatever be the disposition of the proboscis. A definite ring of muscle and connective tissue (usually of a reddish hue in fresh specimens) encircles the sheath at *b*, and marks the boundary of the next section *b-c*. This portion, about

$1\frac{1}{2}$ inch long in the adult, is thin walled, made up of muscular fibres and connective tissue, and is connected by long strands of muscle with the walls of the body cavity. Some of these strands pass backwards for some distance. Now this region can be everted in such a way that whilst forming part of the proboscis sheath in the retracted condition (fig. A), it forms the base of the proboscis in the extended position (fig. B). Thus the protrusion of the proboscis is not due to muscular action of this structure itself but to the unfolding of the hinder part of its sheath. The proboscis is nothing but a further continuation of the body wall, and the true mouth lies as mentioned above at its distal end (figs. A and B, *M.*).

The cavity (part of the external world) between the proboscis and its sheath (Text-fig. 4, *Rhyn.*, and Pl. II, fig. 11, *Rhyn.*) is known as the Rhynchodaeum, and the opening of the latter, or the false mouth, is the Rhynchostome (*Rst.*). Such a proboscis is termed a *pleurembolic proboscis* (Lankester*), from the fact that when withdrawn it is the base that is pulled and disappears first. The other and opposite type is the *pleurekbolic*, met with in the Cypraeidae, etc. The proboscis of *Buccinum* was known to the ancients, and both Aristotle† and Pliny‡ refer to it. Cuvier was the first, however (1817)§, who described it with accuracy and detail.

Pharynx.—The mouth (Text-fig. 4, *M.*, and fig. 11) opens into a muscular pharynx (Pl. II, fig. 12, *Ph.*), the walls of which are attached all round to the proboscis walls by radiating muscles. Into the floor of the

* Lankester. Art. Mollusca, Encyclop. Britannica, 9th edit., Vol. XVI, 1883.

† Aristoteles. De Animal. hist., Lib. IV, cap. 4, §§ 7, 8, 9.

‡ Plinius. Hist. Nat., L. XI, c. 37.

§ Cuvier. Mém. pour servir à l'hist. et à l'anatomie des Mollusques.

pharynx, which bears no teeth, projects the tongue apparatus, and the muscles of this characteristic organ almost surround the anterior part of the alimentary canal. The whole structure is known as the Odontophore (Text-fig. 4, *Od.*), and consists essentially of a tongue, projecting into the pharyngeal space, covered by a flexible rasp—a membrane set with teeth—known as the radula. A description of this apparatus is given separately below.

The pharynx extends backwards for about 1 cm., and almost at the point where the radular apparatus opens into it, two salivary ducts enter laterally, one on either side (Pl. II, fig. 12, *Sal. d.*). These ducts can be seen as two delicate white tubes running along the sides of the oesophagus (fig. 12, *Oes.*), the next portion of the gut.

The Oesophagus extends from the pharynx to the stomach, and is the longest section of the alimentary canal. The most distal part, immediately behind the pharynx, is flattened dorsoventrally and runs along through the proboscis to its posterior end. Here it turns abruptly on itself and runs forward again in close contact with the proboscis sheath. The anterior direction is kept until the region is reached where the nerve collar lies hidden by the conspicuous salivary glands, and then another somewhat abrupt bend occurs (Text-fig. 4, A and B) and the oesophagus passes through the nerve ring and runs posteriorly along the floor of the body cavity. This curious looping of the oesophagus is probably due to the nerve collar which has retained its normal anterior position and compelled the alimentary canal to take the course which has been described. The part of the gut which is thus bent into an **S** is marked by longitudinal folds projecting into the lumen. None of these longitudinal folds are specialised or better developed

than others. At its sides run the salivary gland ducts already mentioned. They arise in the large salivary glands, compact bodies of a yellow colour, which are situated asymmetrically about the alimentary canal and nerve collar. The latter is hidden completely except from below. The left gland lies more posterior and more dorsal than the right, and thus covers part of the latter. The ducts are formed by numerous small branches joining up in the tissue of the glands and leaving them dorsally (Pl. II, fig. 12, *Sal. gl.*). The histological structure of this organ is given below.

Neither gland alters its position during the evagination or invagination of the proboscis, and a further most important point to notice is that *neither salivary duct passes through the nerve ring.*

This is probably due to the fact that with elongation of the proboscis the salivary glands came to lie in front of the nerve collar. With the later elongation of the salivary ducts the salivary glands came to lie behind the nerve collar and moved to the position externally to the collar. This explains the fact that in the *Rachiglossa* the ducts do not penetrate the nerve collar, a feature otherwise common in the *Monotocardia*, where the glands are posterior to the nerve ring.

A little distance behind the nerve collar a narrow tube opens into the oesophagus on its dorsal surface (fig. 12). After running forwards for a few millimetres, it curves round and widens into a very thin-walled bag, usually flattened, and of a brown colour in fresh specimens, owing to the contents. The bag extends back for some distance, lying upon the oesophagus. It is the so-called gland of Leiblein (Pl. II, fig. 12, *Ln. g.*)—the poison gland of the *Toxiglossa*.

Both gland and oesophagus move over towards the

left side as the visceral mass is reached. Just before the region of the pericardium and digestive gland is entered, a peculiar caecum is to be found on the oesophagus (fig. 12, *Ln. g.*). Its walls are rather more thick than the part described above, and resemble the short piece now left between caecum and stomach. The caecum can be easily seen in simple dissections, for the oesophagus has now left the head region and is visible without any incision whatever at the surface of the visceral mass on the left ventral edge. The caecum itself lies just behind the pericardium (fig. 12, *Caec.*).

The **Stomach**—that part of the alimentary canal into which the ducts of the large digestive glands (the so-called liver) open—is a bag of considerable size, with one surface lying against the digestive gland and the other surface against the bounding integument. Thus the stomach is clearly visible without any dissection. Curiously enough, it is attached strongly by short muscle strands to the epithelial layer of the body wall, so that the latter, which can be easily removed from the other parts of the viscera, is only pulled away with difficulty from this area.

The stomach (fig. 12, *St.*) is very irregular in shape. It is flattened, so that there are two more important surfaces, and it is elongated in an antero-posterior direction. The oesophagus opens into it ventrally about midway between the point of origin of the rectum and the posterior apex of the stomach. Just before entering the stomach the oesophagus passes under a somewhat conspicuous lobe of this organ, which is marked with radiating striae and lies between oesophagus and intestine (fig. 13, *Dg."*).

The markings on the external surface of the stomach correspond to ridges which occur on the inner surface and

project into the lumen. Two openings into the stomach, both on the inner surface, mark the entrance of the ducts from the digestive gland (fig. 13, *Dg. d.*). One of these is situated anteriorly close to the proximal part of the rectum, the other is just posterior to the point of entrance of the oesophagus.

The Digestive Gland is the largest structure in the visceral mass, and extends from the pericardiac region to the tip of the spire. It is brown or brown-green in colour, and soft and oily in consistency, with no very pleasant smell. This large gland, which is made up of fine branching tubules, was formerly regarded as a "liver." It is now agreed that this name is unsuitable, as the digestive functions are more comprehensive and unite the functions of the different digestive glands of the vertebrate gut. It is, furthermore, the chief organ in the body for absorption of digested food.

Originally the digestive gland of the Gastropoda was paired and symmetrical. In the adult *Buccinum* there is an obvious division into right anterior and left posterior lobes. The latter is much the larger of the two and extends from the tip of the stomach to the end of the spire. The boundary of the two regions lies at the posterior end of the renal organ. The paired nature is still further indicated by the fact that the tubules, of which the gland is composed, open into one another, and finally form two large ducts which enter the stomach, as mentioned above. The posterior part of the digestive gland is partially covered by the gonad which lies, forming a kind of arch (fig. 58), on its dorsal surface.

The Intestine (fig. 12, *Rect.*), the original posterior portion of the gut, is of shorter length than the oesophagus. Owing to the torsion which has taken place in development it runs forward dorsally to open into the

pallial cavity. The intestine leaves the stomach dorsally and anteriorly and lies close to the surface until the renal organ is reached. It then plunges underneath the latter (though still on the surface of the digestive gland and outside the pericardium), and reaches the pallial cavity.

It is now some distance away from the oesophagus and ascends into the wall of the pallial cavity, taking a course along the right side at the extreme edge. In the female this distal portion, the rectum, is compressed by the oviduct. The rectum terminates in a conical protuberance at the end of which the anus is situated (fig. 8, *An.*). With the exception of glandular walls, no special anal or rectal glands are present.

HISTOLOGY OF THE ALIMENTARY CANAL AND RELATED ORGANS.

A detailed account of the histology of the whelk's tissues would be far beyond the limits of this Memoir. Only some of the more typical and important structures will be referred to here.*

The Pharynx.—The pharynx in life has a peculiar pink colour, due to its muscular wall. In sections one finds the lumen of the gut lined by a layer of deep epithelial cells. As a matter of fact, the lining of the gut is very similar throughout its length, and the same kinds of cells are found in the epithelium, viz.:—(1) Ciliated cells, (2) Eosinophilous cells, (3) Gland cells. Whatever may be the function of the two latter types, it is interesting to notice that they occur throughout the whole length of the gut from pharynx to rectum.

The ciliated cells (fig. 24, *Cl. c.*) are typical tall

* The author intends to publish shortly a series of papers dealing with Molluscan Histology.

columnar epithelial cells, with an oval nucleus situated near the middle of the length. A distinct border, due to the desmochondria at the base of the cilia, is present. With either methyl-blue-eosin, or Mallory's stain, the contents of the eosinophilous cells (small spherical granules) (fig. 24, *Ev. c.*) stain an intense red and the contents of the gland cells light blue (fig. 24, *Gl. c.*).

The most interesting part of the pharynx is, however, its muscular sheath, which underlies the epithelium. It may be divided into two layers, longitudinal fibres situated next to the epithelium, and an outer circular muscle layer (fig. 24, *Mus. long.* and *Mus. circ.*). There is no outer layer of epithelium bounding the cavity in which the pharynx lies, for this is simply a haemocoel. The muscle fibres are extremely thick, and each is surrounded by a capsule of connective tissue. This matrix is, however, so reduced that it has rather the appearance of very thick cell walls, where the muscle fibres are cut transversely. The fibres themselves resemble the cell contents, for they are almost round in transverse section; the angular shape really possessed by them is probably due to crowding and pressure. The structure of the fibres is extremely distinct in this pharyngeal musculature, and one sees a beautiful peripheral arrangement of fibrils surrounding a large central granular sarc, in which may sometimes be seen the nucleus. A better or more easily procured example of this type of muscle fibre could hardly be imagined. These large fibres with their great sarcoplasmic centres give the reddish pink tinge to the pharynx, a colour which is hardly ever present in molluscan muscles, and in the whelk in one other place only, the muscles of the odontophore.

The Gland of Leiblein.—So far as I am aware, no

description of the structure and chemistry of this gland exists. In life the gland possesses brownish contents which can be seen through the delicate walls. It is homologous with the so-called poison gland of the *Toxiglossa*, and, as stated above, belongs normally to the ventral side of the oesophagus. Its opening has been brought to the present dorsal position by the torsion of the alimentary canal in this region.

The walls of the sac are formed of a delicate layer of connective tissue (fig. 30, *Con. t.*), which is, at the same time, a supporting membrane for a stratum of peculiar cells which line the cavity. These are extremely long pear-shaped cells which are attached to the basement membrane by their narrow ends. They have the appearance of loosely adhering cells, sometimes looking like contracted Infusoria, attached by narrow stalks and protruding swollen sac-like portions into the lumen of the gland (fig. 30, *Gl. c.*).

The cells themselves are of all sizes, and vary from ordinary columnar epithelial cells to the elongated pear-shaped kind. There is no doubt that all the cells are of one category, and the differences observed are merely those of growth. In all cases the nuclei, which are elliptical in shape, are to be found near the bases of the cells. The cells are well filled with protoplasm and crowded with brownish yellow granules. In the sections so far examined the lumen of the gland has contained numerous cell remains, and it is evident that dehiscence of the whole cell, or at least part, takes place when filled with the brown granules.

The function of this gland is at present problematical, and I do not know on what evidence the term poison gland, as applied to the homologous structure in the *Toxiglossa*, has been given. It could hardly function as

a poison gland in the whelk, opening, as it does, so far back. It is in all probability a digestive gland, but it might function as an "antiseptic."

The Salivary Glands possess an extremely compact structure. They become brittle in preserved specimens, and are most difficult to cut when embedded in paraffin.

Sections show that after the salivary ducts break up in the gland, the branches dividing into finer tubules in their turn soon end through complete occlusion of their cavities. Sections of the ducts with their columnar cells bearing cilia (fig. 26, *Sal. d.*) are met at irregular intervals, but the greater part of the tissue is composed of groups of large intensely vacuolated cells (fig. 26, *S. gl. c.*). These large cells become continuous with the epithelium of the ducts, but, unlike the gastric gland cells, they are so large that the cavity of the ductule soon ceases to exist when the walls are formed of them. In most of the cells a trace of protoplasmic contents at least remains, and there is a distinct nucleus. The rest of the cell is either one large vacuole with colourless non-staining contents, or is filled with bodies of irregular shape and very variable size, which stain intensely with eosin (fig. 26, *S. gl. c.*).

In some gastropods the secretion of the salivary glands contains a large amount of free sulphuric acid, which is supposed to aid in the boring of calcareous shells. No marked acid reaction could be obtained with the whelk secretion. Griffiths finds that the gland has the same function as that of *Patella*, and contains a ferment capable of transforming starch into glucose.

The Oesophagus.—The section figured has been cut not far from the caecum (Pl. III, fig 25). It has already been mentioned that longitudinal ridges run along the lumen of the oesophagus. These can often be seen from

the exterior, but *not* because the external surface is thrown into folds. It is only the internal layers that are folded, so that as a result the walls are alternately thick and thin. There is no external epithelial layer bounding the alimentary canal, for it runs through a haemocoel and not a true body cavity bounded by an endothelial layer. One finds, therefore, most externally, an attenuated connective tissue layer (fig. 25, *Oe. con.*). This gives place to compact dense connective tissue, through which run many muscle fibres (fig. 25, *Oe. con.*!). Externally, the circular or transverse muscle fibres predominate, internally one finds longitudinal fibres, and this layer is particularly thick and forms the main substance of the folds. The connective tissue sheath is divided, therefore, into two distinct layers by reason of the muscles which run through it. The inner layer with the longitudinal muscles varies in thickness according as to whether it is under a groove or a fold, and forms the support for the epithelium which lines the gut.

The Epithelium is composed of regular columnar epithelial cells, the height of which is about twelve or more times the thickness. There are three kinds evident, viz.:—(1) Ciliated cells, (2) Eosinophilous cells, and (3) Gland cells, and their frequency is in the order given above, the gland cells being least numerous.

The ciliated cells are very narrow basally, but increase in thickness towards the lumen, and their surfaces form a distinct unbroken plane. They are typical ciliated cells and show very distinctly the double row of desmochondria at the base of the cilia, and the connecting fibres in the cytoplasm.

Between these cells occur the eosinophilous cells in great numbers. They are more common here than anywhere else, and are crowded with small granules which

show a most marked avidity for eosin. The gland cells stand out very distinctly in methyl-blue-eosin stained preparations, for their contents appear light blue, whilst the epithelium generally is a dense red, a granular red!

They do not occur in very great numbers. In some sections the lumen of the oesophagus is filled here with the blue stained contents of these gland cells and the red stained extruded cells. Eosinophilous granules also abound in the secretion.

The Caecum.—The caecum differs from the part just described in having the simple folds of epithelium and connective tissue thrown into most complex secondary folds. Thus the lumen is split up and reduced in size, and the connective tissue is reduced to a thin layer between the folds of epithelium.

Another important and obvious distinction is that the eosinophilous cells have become much reduced in number, and hence the lining epithelium has almost lost the granular densely stained appearance. A few scattered gland cells are to be found. What the function of this caecum may be it is difficult to say, for the walls are not in the least like the walls of a gland, and gland cells are reduced in number.

The Stomach.—In structure the wall of the stomach does not differ essentially from the rest of the alimentary canal. The cavity is lined by a layer of columnar ciliated epithelial cells (hexagonal in transverse section), which are perhaps not so long nor so slender as the cells of the rectum, but resemble them closely. Amongst these cells are scattered eosinophilous cells of the same character as those found elsewhere in the walls of the gut. Gland cells occur but rarely. The nuclei of the epithelial cells are to be found nearer to the basal membrane than those of the cells of the remaining parts of the digestive

tract. Underlying the epithelium is a thin but distinct basal membrane, and below this a layer of connective tissue with muscle fibres.

Numerous large blood spaces occur in the connective tissue, so that it may practically be said that the stomach lies in a blood cavity.

The conspicuous grooves, which have already been referred to as occurring on the inner surface of the stomach, are produced by variations in height of the epithelial cells. In this respect the epithelium agrees with the same layer in the stomach of the lamellibranch *Pecten*.

The Digestive Gland.—This large gland has been known as the liver, the Hepatopancreas, and the Gastric Gland. It is now regarded as a “pancreas,” but with additional functions, such as storing pigment and fat. The term liver should certainly be abolished and replaced by the name “digestive gland.”

The gland is tubular, and is formed by repeated division of the ducts which open from the stomach. These numerous branches ramify still further, and eventually end blindly as caeca. The gland, like that of *Pecten*, is composed almost entirely of these caeca and ductules, and the connective tissue which encloses each ductule and caecum, and is therefore to be seen between them, is reduced to a minimum. There are numerous blood lacunae penetrating between the caeca.

The appearance of stained sections is very characteristic, for almost all the gland cells are crowded with large, oily-looking granules, which stain vividly with eosin (fig. 29, *Dg. gr.*). They are so numerous, in fact, that details of cell structure are almost entirely obscured. Commencing from the opening of a ductule into the stomach, and passing towards the blind end of one of its

branches, the following changes are to be noticed in the character of the cells. The walls are at first made up of ciliated columnar cells (fig. 29, *Dg. c.'*), which resemble those of the stomach. The protoplasm is distinctly seen here, since there is little or no secreted or absorbed substance. These cells are gradually replaced by more and more vacuolated ones (fig. 29, *Dg. c.''*), containing the intensely staining bodies. Cilia disappear, and finally the typical broad cells almost meet in the centre, so that the cavity becomes very narrow, almost occluded, as the end of a caecum is reached.

There are usually said to be three kinds of cells present in the digestive gland of molluscs—ferment cells, granular cells (liver cells), and lime cells. It is extremely difficult to make out these different types in the whelk. Very occasionally cells are met with which are possibly lime cells, but most cells are alike in containing the oily or fatty bodies already referred to. Whether it is really possible to draw a distinction between ferment cells and granular cells is very doubtful. It is probable that both are merely stages in the life of the same cell.

Intestine.—The intestine differs hardly at all in structure from the oesophagus. There is the same layer of very tall and narrow epithelial cells, with long cilia. Gland cells, however, are far more numerous. The eosinophilous cells are present in considerable numbers as before. The lumen contains large quantities of the granules from the latter cells, and considerable numbers of extruded cells or parts of cells.

THE ODONTOPHORE.

The complex odontophore of the whelk was examined by Geddes in 1878. He does not describe the structures in detail, but gives figures of some dissections.

In order to expose this organ, the proboscis should be removed and pinned down with the dorsal surface uppermost. If a cut is made down the middle line and the flaps folded back, the whole apparatus lies somewhat as figured in Pl. III, fig. 19, the oesophagus resting on the odontophore.

Now the odontophore consists essentially of a band (the radula), to which are attached a large number of muscles. This band is fixed, pulley-like, on a grooved support, which we shall call the odontophoral cartilage. The whole structure is bound together by two delicate sheets of transverse muscle fibres. One of these will be seen immediately the oesophagus is removed, and lies dorsally, forming a roof over the radula and cartilage (fig. 19, *d.m.s.*). Two dorsal protractor muscles (fig. 19, *d. pr. m.*) run from the anterior end of the proboscis walls to the odontophore. In addition to these, the walls of the buccal cavity are muscular, and there are two delicate ventral protractor muscles (fig. 18, *v. pr. m.*). It seems probable that protrusion of the odontophore (it can be brought up to the mouth opening), is aided by blood pressure, in addition to muscle action.

A conspicuous central dorsal muscle (figs. 19 and 16, *C.d.m.*), which is attached to the extremity of the radula (dorsally), extends back over a large number of other muscles, all of a faint red tint, to become attached to the floor of the proboscis. At the sides of these muscles are two peculiar straps, consisting of a connective tissue matrix with numerous muscle fibres (figs. 16, 18, 19, 20,

L.t.b.). These are extremely important structures, and run back a considerable distance, to branch finally and become attached to the floor of the proboscis. They will be termed the *Lateral odontophoral bands*. These bands form the meeting place at their anterior extremities for a number of dorsal and ventral muscles and the odontophoral cartilage. Thus many of the muscles of the radula are not attached to the walls of the proboscis directly, but to two lateral musculo-connective tissue bands. Neither Geddes nor Oswald have figured this muscle connection with the lateral bands correctly.

The odontophoral cartilage is formed of two long band-like lateral cartilages, which are much thicker at their anterior ends and somewhat L-shaped in section. They fuse ventrally at their anterior ends, and thus by reason of their shape form the walls of a gutter or groove open dorsally (figs. 20, 18 and 23). In addition, they are united posteriorly by the sheet of transverse muscle fibres, the companion structure to the dorsal sheet already noticed (fig. 18, *V.e.m.*).

Upon this odontophoral cartilage lies the radula. There is usually about 20 mm. of it on the dorsal surface, and 10 mm. on the ventral.

The muscles of the odontophore may be divided into:—

I. Muscles attached to radula, (*a*) dorsally, and (*b*) ventrally;

II. Muscles attached to odontophoral cartilage;

or

I. Protractors, (*a*) of Pharynx, and (*b*) of Radula and Cartilage.

II. Retractors, (*a*) dorsal, and (*b*) ventral.

The protractors of the Pharynx consist of two muscles which run dorsally from the anterior end of the

proboscis to the posterior end of the pharynx. By contraction of these muscles the pharynx can be moved forward.

The protractors of the Odontophore have already been referred to. They are first a pair of muscles which run from the walls of the proboscis to the sides of the odontophore, really to the lateral "cartilages" of the odontophore, and a pair which are situated ventrally and anteriorly (figs. 18, 21, *V. pr. m.*). These are also inserted in the odontophoral cartilages. In addition to these might be included the muscles of the buccal cavity walls, which are attached to the radular sheath. The action of all these muscles is to pull forward the radular apparatus.

The Retractor muscles are much more complicated, and are at first somewhat difficult to follow. There are two series of these muscles, dorsal and ventral, lying above and below the odontophoral cartilage respectively. The dorsal retractors are much more numerous, and larger than the ventral, and, as will be seen later, this is to be correlated with the movements of the radula and the arrangement of teeth on the same.

The first retractor to be observed is the most dorsal unpaired median band (fig. 16, *C.d.m.*), which is attached to the end of the radular sac, and after running back some distance is inserted into the walls of the proboscis.

Before referring to the other dorsal retractors attached to the radula, mention must be made of two curious muscles which run from the end of the radular sac, at the point of insertion of the central dorsal muscle, to the two cartilages (fig. 16, *c.c.*). They are thus fixed to two apparently unstable points. The action of these dorsal ocluser muscles and the median dorsal muscle is interesting, for the contraction of the former will bring

the two cartilages together, closing the gutter and preventing the radula from slipping up over the sides, whilst the contraction of the median muscle will pull back the radular sheath and even the pharynx.

There still remains a large number of retractor muscles attached to the dorsal portion of the radula. Of these, two on each side arise from the anterior ends of the *lateral odontophoral bands* (or the posterior ends of the odontophoral cartilages), and are inserted laterally to the radular sheath (fig. 16, *l.r.r.'*, *l.r.r."*). The others all arise on the floor of the proboscis wall some distance posteriorly. They comprise (1) the median muscle lying under the centre dorsal muscle (fig. 16, *c.d.m. inf.*), (2) the paired muscles (fig. 16, *r.'*, *r."*), and (3) the paired muscles (fig. 16, *V. r.*).

Altogether, there are four or five pairs of muscles running together in this way, and all are attached laterally and ventrally to the radular sheath some distance forwards.

The Ventral Retractors are much inferior in strength and number to the dorsal muscles. Like the latter, they are attached both to the floor of the proboscis sheath and to the anterior ends of the lateral odontophoral bands. In fig. 18, the ventral muscles are supposed to be seen *through* the odontophoral cartilage, all the dorsal muscles and dorsal part of the radula having been removed. It will be seen that on each side there is a bi- or tri-partite muscle, the lateral ventral retractor, which runs from the lateral tongue band, and is attached in front to the sides of the radula (figs. 17 and 18, *v.v.m.*). In addition to these there are two median ventral muscles (fig. 17, *m.v.r.*), which lie in close contact with the ventral sheath of circular-muscle fibres (fig. 18, *v.e.m.*), and then run back to be inserted in the same region as the dorsal retractors, the floor of the proboscis.

In regard to the mode of action of the apparatus, Huxley came to the conclusion that the "cartilages" which support the radula were perfectly passive and that the radula was pulled backwards and forwards, as a strap over a pulley or a polished surface, so that it scraped the object like a rasp or file. This was the result of observations on some living gastropoda. Geddes held the opposite view, a view formerly hinted at by Cuvier, to the effect that the action of the radula was due to the muscles pulling the whole tongue up and down.

My observations lead me to support Oswald, who asserted that both these movements played a part; but those described by Huxley seem, at the same time, to be the most important.

The mere fact of the attachment of the muscles to the odontophoral cartilage shows that this is not altogether passive. Again, the effect of the dorsal retractors pulling on the radula would be to cause the cartilage to move dorsally, but this would only happen to any extent *if the radula were fixed securely against the cartilage*. Most of the muscles, however, are inserted in such a way that much power would be lost if they were only moving the cartilages; in fact, it would be difficult to account for their positions. Furthermore, there can be little play for the cartilage in the securely bound up odontophoral mass. One would conclude, therefore, from the anatomy alone that the rasping movements of the radula over the cartilage were the most important, whilst at the same time this structure was not altogether passive. Any doubt, however, was dispelled by one of the whelks actually attacking the finger of the author and rasping away for a few seconds on the skin. The median teeth of the radula are so placed that at the point of reflection of the

latter over the tongue they point upwards. It is not easy to see how they could be of much use in boring if they remained in this position. One sees here perfectly clearly the reason for the powerful dorsal musculature. When the radula is pulled by the ventral muscles the teeth slip backwards over the object with little friction since they are pointing the other way, but when the dorsal muscles contract, the teeth are directed against the object and much resistance has to be overcome.

The action of the radula can, as a matter of fact, be easily demonstrated in whelks that have been narcotised. If the proboscis is removed from one of these animals and squeezed between the finger and thumb gently, the odontophore will be protruded, and the application of a little pressure to a spot which can be found by trial will cause the radula to move backwards and forwards over the cartilage.

The action of the muscles, so far as I have been able to determine, is as follows:—By contraction of the dorsal retractors, the radula is pulled so that the teeth rasp the object. At the same time the occlusor muscles come into action and hold the sides of the cartilage together, so as to maintain the groove. I find no evidence whatever to show that by contraction of these muscles the radula comes to lie *on* the sides of the cartilages as stated by Oswald. On the other hand, the position of the lateral teeth show the necessity of the groove, for as they pass from the plane ventral surface of the tongue to the gutter-like dorsal surface, they “bite” inwards, and so the net result is a tri-partite attack on the object.

The ventral muscles now come into play and draw the radula easily backwards. There would be no point in the arrangement of the lateral teeth whereby they can rotate inwards and act in a most efficient manner, if

movements of the radula over the cartilage were not the usual method of attack.

The radular teeth (fig. 14) are, in accordance with the Rachiglossan formula, three in number, one median and two lateral. The median teeth, known as the central or rachidian, are placed with their anterior margins exactly transversely across the radula and possess a number of similar denticles which will be referred to again below. A thickened yellow band marks the position of the tooth itself. All the teeth are fused to the chitinous radular band. The lateral teeth are set obliquely, and almost alternate in position with the centrals. The inner end of a lateral tooth lies almost opposite the base of a central tooth, whilst its outer end is opposite the next posterior central. Furthermore, the lateral teeth are not exactly on the same plane as the centrals, and as the radula passes into the lingual groove they are caused to rotate until their denticles are directed towards the middle line. The denticles of the lateral teeth are much larger than those of the centrals and vary in shape, the outermost being by far the most powerful.

On the whole, the radular teeth are very regular and characteristic in the gastropoda, and are commonly used for purposes of classification. The teeth of *Buccinum undatum*, however, make a very striking exception to this rule, since the number of denticles on both the central and lateral teeth varies in an extraordinary manner, giving an excellent example of meristic variation. The three first radulas taken from Port Erin whelks varied in number of denticles as follows:—

Lateral teeth:—4. 4. 4

Central teeth:—6. 7. 8.

Bateson records that from 27 specimens the variations were as follows:—

Lateral	-	4.	4.	4.	4.	4.	3 & 4.	3 & 4.	4 & 5.
Central	-	5.	6.	7.	6-8.	9.	6.	7.	8.
Cases	-	8.	12.	2.	1.	1.	1.	1.	1.

It will be seen that even the bilateral symmetry may be destroyed, the opposite lateral teeth having a different number of denticles. Furthermore, though in almost all cases the teeth are the same on the one radula, there have been observed specimens where the number of denticles on the anterior central teeth was less than the number at the posterior end of the radula.

HISTOLOGY OF ODONTOPHORAL CARTILAGE AND RADULAR MUSCLES.

The cartilage of the molluscan radula (fig. 23) represents probably the earliest development of cartilage in the animal kingdom, and by reason of its distinctness and ease of preparation it is a good example for the study of invertebrate cartilage.

The most external bounding layer is a delicate connective tissue, which encloses the cartilage cells. The cartilage itself has the appearance of a plant tissue. It seems at first sight to be composed of very large irregular cells with small round nuclei and extremely definite and deeply staining cell walls. The cells (fig. 22, *Cart.*) are 18μ in diameter, turgid with fluid, and contain a delicate fibrillar protoplasm which does not stain intensely owing to its attenuated state. The nuclei (fig. 22, *Nuc.*), which are perfectly spherical, are only 4μ in diameter. A nucleolus is usually present and many small granules of chromatin. The apparent cell walls are in reality the intercellular matrix formed by the cells. This is small in quantity and is formed in such a regular manner that it has the appearance of cell walls rather than a matrix. This pseudo-wall, if followed,

often appears to be continuous round two or more cells (fig. 23). The more cells round which it is continued the thicker it is, and hence in places there appear to be septa running into the mass and forming at the same time the bounding walls of contiguous cells. The cartilage of the molluscan odontophore has often been referred to by writers, but has apparently never been examined in any detail. It has been compared to cellular or vesicular connective tissue, or called cartilage without micro-chemical tests. Josef Schaffer seems to be the only worker who has examined it in any detail, but his paper has appeared only as a resumé without illustrations. The main conclusion is that the "cartilages" vary towards or away from a distinctly real cartilage, and that the development of a low or high type of cartilage is to a certain extent independent of the phyletic position of the animal. The Buccinum cartilage is most certainly a real cartilage. Micro-chemically it reacts in a slight but distinct manner to thionin, giving the characteristic muco stain. It is therefore to a certain extent a muco-cartilage.

The odontophoral cartilage is not entirely composed of cartilage tissue, as the dorsal portions of the walls of the groove (fig. 23, *Ling. con.*) are of a very compact connective tissue, composed of a matrix resembling the intercellular matrix of the cartilage area, but penetrated by a large number of muscle fibres.

The muscle fibres (fig. 22) of the radula are also striking in structure. They are red in colour, and contain much sarcoplasm. Each muscle cell is a spindle-shaped structure of considerable length. In section it is circular, and the diameter of these fibres is considerable, 15μ . The sarcostyles (fig. 22, *Mus. col.*), or actual contractile elements, are arranged round the periphery of

the muscle cell, and the large remaining central space is occupied by the sarcoplasm. Thus in any transverse sections of these muscles, the fibres are represented by circular discs, the centre of which is granular protoplasm, whilst the periphery is either a dark staining circle or this may have been resolved by the stain into a number of segments—each a transverse section of a sarcostyle. The sarcostyles do not run quite longitudinally along the muscle fibre or cell, but wind spirally round it. Thus a delicate double striation is present, but cannot be seen unless one focusses completely through a fibre.

The Radula, with its teeth, is being formed continually by the cells of the radular sac in which its posterior dorsal extremity lies, and as the teeth of the anterior region are broken away in action, new regions move forwards and take the place of the old. The radular sac is a delicate cellular caecum continuous anteriorly with the epithelium of the pharynx. It ends blindly at the point to which is attached the centro-dorsal retractor muscle (figs. 19 and 16, *C.d.m.*). The cells forming the wall of the blind end are known as **Odontoblasts**. These secrete the teeth and the basement membrane which bears them. In *Buccinum* the odontoblasts are very numerous and exceedingly narrow.

Their length, however, varies in a regular manner according to position, so that cushions of cells are formed. Transverse and longitudinal sections are both required to elucidate the structure of the radula sac. The transverse section (Text-fig. 5, A) gives the key to the structure, for it is seen that the radula near and up to the point of origin is so fixed that the lateral portions with the lateral teeth are turned up at right angles to the median area. The cells of the radula sac are longest at the extreme end, where the radula is formed. As a matter of fact, the

external surface of the sac at this point forms a perfect circle in transverse sections (Text-fig. 5).

The cells of the lateral and basal walls of this circular sheath are of medium length. The cells of the dorsal wall are of extraordinary size and extend down into the cavity, forming a deep ridge, which extends for some distance from the blind end. This odontoblast ridge lies, of course, in the gutter formed by the radula. Thus one sees that the cells of the lateral and ventral walls are directed towards the basal ventral plate of the radula, whilst the dorsal ridge cells are directed towards the teeth, both median and lateral.

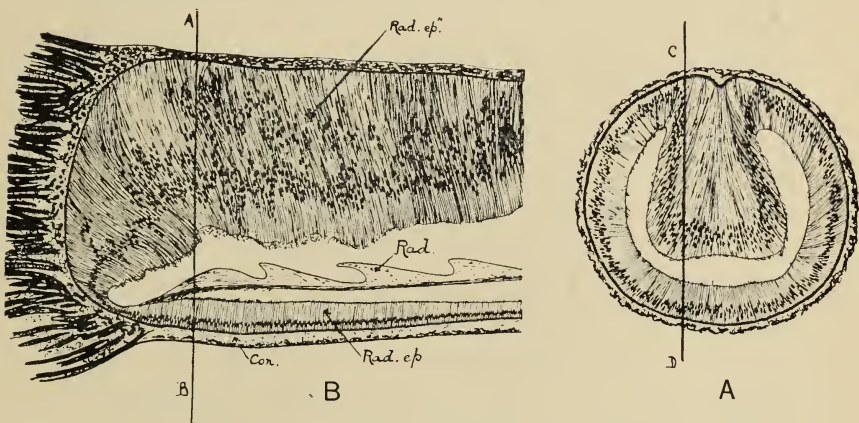


FIG. 5.

As one passes towards the pharynx the depth of all the cells decreases, the dorsal ridge passes away and gradually the ordinary epithelial type is reached continuous with the epithelium of the pharynx.

The nuclei of the odontoblast cells are oval, more or less elongated and contain numerous small granules. The most characteristic feature of the odontoblast, however, is the free end of the cell. The secretion leaves it

in the form of numerous cilia-like processes which, in a Mallory-stained section, are at first red in colour. They soon become blue or purple as one passes from the cell, and then lose their individuality in a homogeneous blue stained mass of chitin, which forms the basis of the ribbon and teeth. The fibrous ground can be detected everywhere in young teeth stained with Mallory's connective-tissue stain. In the whelk the teeth are absolutely continuous with the basal membrane of the radula, and it is almost impossible to make out any line of junction or to say which cells have participated only in the fabrication of the teeth. The ventral and lateral cells of the blind end have, however, most certainly played the greater part in the formation of the ribbon membrane and the dorsal cells, the teeth.

One point, however, of great importance is that the ventral and lateral cells are still connected with the radula by the cilia-like tags some considerable distance away from the blind end, and the same applies to the dorsal cells. This probably indicates that when the point of the radular membrane (in this attached region) was at the extreme posterior end of the sac, the cells below it were there too. In other words, just as the radula is secreted and pushed forwards, so do the odontoblasts move forwards with it, and new ones are formed at the blind end of the sac. There are at present two views on this subject. One is that the odontoblasts, very many of which secrete one tooth, remain functional after that tooth has been formed and go on secreting the next, and so on. The other view is that the odontoblasts have performed all they are capable of in secreting one tooth and that they pass forwards to be replaced by new cells. Obviously they have to become much smaller. The sections of the

whelk's radular sac favour, then, the latter theory. The very young teeth are probably entirely formed of chitin. Certainly there is no differentiation given by stains. They very soon become hardened by the deposit of mineral salts, but they differ, as do all other Odontophora, very considerably from the Docoglossa, where the teeth contain a remarkably large proportion of silica. According to Miss Sollas, the composition of the teeth of *Littorina* is:—Ash 3·7 per cent. containing iron, calcium and magnesium, while the rest is organic matter, the basis being chitin. In the Docoglossa, on the other hand, the mineral matter may amount to as much as 27 per cent. (*Patella vulgata*)—silica hydrate being present in large quantity.

Outside the odontoblast layer is a very compact connective tissue layer, and it is in this connective tissue that the muscles, which are attached to the radula, terminate. The muscles are of the type described above. Their terminations can be followed very beautifully indeed in sections stained in Mallory, for the muscles are bright red, and the connective tissue bright blue.

BLOOD VASCULAR SYSTEM.

The vascular system of some molluscs has attained a high degree of complexity. This is especially the case with the Cephalopoda and some of the Prosobranchiata, and the whelk amongst the latter may be taken as showing a good example of a well developed molluscan blood system. It seems that, at the present day, in many zoology courses there is a tendency to pay little attention to the vascular system of the molluscs. The cephalopods receive perhaps adequate treatment, and possibly the snail (*Helix*) has some attention.

In most cases, however, beyond the heart and large vessels leaving it, very little is investigated. Now in the whelk it is quite easy to demonstrate all the more important facts in connection with the circulation, and if a little care is used in injecting, there is no reason why this method should not be adopted in the ordinary laboratory classes for senior students. Very few complete accounts have been given of prosobranch blood systems, and it is hoped that this description will serve as an aid in the study of an excellent and exceedingly common type.

A great part of both the venous and arterial systems can be made out from the surface, without any dissection. All the vessels shown in figure 35 on Plate V can be seen, with the exception of the dotted trunks which run in the foot. This means that a cold injection mass may be used, without troubling to employ any of the complicated and unsuccessful mixtures which have been invented in order to attain solidification or coagulation in the vessels.

D I R E C T I O N S f o r I n j e c t i o n .

For students' purposes, two very simple injecting masses will suffice:—

1.—*Cold Injecting Mass.*—Use one of the familiar collapsible tubes of artists' oil colours. Chrome-yellow is a convenient tint. Squeeze this into a dish and dilute with turpentine, stirring until a slightly thick but uniform mixture is produced.

2.—*Hot Injecting Mass*, for studying the deeper vessels.—Melt down one or two pieces of ordinary table jelly in an evaporating dish, adding water if necessary. Add to this some carmine, rubbed down with a small quantity of water in a mortar and stir until a uniform mixture is obtained which will solidify on cooling.

It is absolutely essential that the whelks to be injected be dead, and further that they have died in a thoroughly lax uncontracted state. The best means is to allow the whelks to expand in a small quantity of sea-water and then add carefully a few drops of a 2 per cent. solution of cocaine in 90 per cent. spirit; and continue adding gradually a little of the cocaine solution. It will be found that three days are necessary before the animals become irresponsive to stimuli. By that time the water is probably in very bad condition, but the whelks will not be seriously affected by this, so far as injection is concerned. The shell should now be removed piece by piece with a pair of bone forceps, and great care must be taken that the soft tissues are not damaged. The columellar muscle should be detached from the shell with a scalpel.

On the external surface the position of the mucous gland and the gill should be made out. Those two organs of the pallial complex with the osphradium can be seen through the mantle. The pericardium has been already seen, lying at the side, and under, the kidney.

Injections can be made from three places.

1.—The syringe should be inserted into the efferent branchial artery, with the point towards the heart. This vessel can be seen quite easily, forming the ventral boundary of the gill. If the paint mixture is used, a very clear view will be obtained of the branchial vessels, the vessels of the mucous gland, and the reno-mucous vessel (fig. 35, *Mu. gl.*, *Br. v.*, *R. sin.*). The auricle will be filled, and probably the efferent renal vessels (fig. 35, *Ren. eff.*).

2.—The point of the syringe should be plunged into the foot, so that it reaches somewhere in the space in which the alimentary canal and poison gland lie. This injection will fill the extensive venous sinus, and then

the veins bringing blood back from all parts to the renal organ. They can be seen by removing the auricle and ventricle from the pericardium, and by slitting the renal organ along its left ventral margin and thus laying bare its internal surface.

3.—The syringe should be inserted into the aorta (figs. 35, 36, *40.*) at the point where it leaves the ventricle. This injection should be performed with the hot jelly, but it is the most difficult one and often fails. The arterial system is injected by this means.

THE HEART.

Buccinum possesses (as do all Monotocardia so far as is known, except *Cypraea*) only one auricle (the left one of the lower Gastropods).

The auricle and ventricle lie in the pericardial cavity, which is bounded by the renal organ and the digestive gland, the auricle being anterior.

The auricle is a very thin-walled sac, capable of considerable extension. It is somewhat like a pear in shape with the pointed end situated ventrally, and into this end opens the efferent branchial vessel.

There are two other openings into the auricle which are situated at the dorsal end. One of these at the anterior edge of the pericardium is the opening of the nephridio-cardiac vein, the other, which is situated on the posterior surface, is the opening into the ventricle. The latter, the auriculo-ventricular passage, is guarded by a valve so that blood is prevented from passing backwards from ventricle to auricle.

It will be noticed that the nephridio-cardiac vein opens directly into the auricle and not into the efferent branchial vessel. It is often somewhat difficult, however, to determine whether the vein enters near the opening of

the branchial vessel and lies along the anterior margin, or whether it enters more dorsally.

The ventricle is very different in appearance from the auricle. It is roughly spherical, with very thick spongy walls, but the cavity is so much reduced by crossing muscles that the consistency of the whole is very like that of a sponge. Injections into the ventricle hardly ever succeed, because most of the injecting fluid oozes out at the point of insertion of the syringe.

ARTERIAL SYSTEM.

From the ventral pole of the ventricle a single vessel arises, the Aorta (figs. 35, 36, *Ao.*). This is of very short length for it divides almost immediately into two branches, the anterior or Cephalic aorta (figs. 35, 36, *A.c.*), and the posterior or Visceral Aorta (figs. 35, 36, *A. vis.*). The Anterior Aorta gives off immediately a small vessel (fig. 36, *a.'*) which sends branches to the oesophagus and the columellar part of the spire and then plunges below the floor of the mantle cavity into the large sinus in which lie the oesophagus, salivary glands and proboscis. The aorta lies at first at the left side but soon crosses over the oesophagus and runs under the salivary glands. Just after entering the body cavity, it gives off a vessel on the right side which passes to the columellar muscle (fig. 36, *A. col.*) and branches on its surface. The next large vessel leaves the under surface of the Cephalic Aorta (fig. 36, *A. pall.*) and passes through the muscles to reach the surface of the mantle. It divides into two main trunks, of which the ventral one reaches the surface on the under side of the animal, and the dorsal vessel just below the osphradium (fig. 35, *A. pall.'*).

This dorsal pallial artery supplies the siphon, and

runs round the edge of the mantle, giving off branches on both sides. Very small vessels leave the aorta at intervals and pass to the alimentary canal. The next two vessels which arise are asymmetrically placed. They leave the aorta laterally, but the left one is somewhat posteriorly situated. These vessels (fig. 36, *A. cut.*), after passing out laterally, run up the walls of the body cavity and break up into small vessels innervating the roof (the floor of the mantle cavity). The vessel on the right side, however, gives off an additional branch (fig. 36, *A. cut.*'), which bores into the wall and passes to the tissues below the ovary and rectum.

The Cephalic Aorta passes forwards until the Nerve Collar is reached and then breaks up at one point into several vessels. The point where this division takes place is hidden by the salivary glands and by connective tissue.

One large vessel runs down at right angles to the course of the Cephalic Artery. This is the Pedal Artery (figs. 36 and 35, *A. ped.*). After a short course, it divides into two branches which make their way into the foot, branch again (each in a similar way) and supply the musculature. These blood vessels are of considerable size. Here they branch, but most of their small branches, which form almost a capillary network, are not shown in the figures. It is by means of this network, and the forcible action of the blood, that the great expansion of the foot is effected.

Returning to the nerve collar region, it will be seen that another large vessel runs dorsally, also at right angles to the aorta. This artery, the Buccal (fig. 36, *A. buc.*), goes forward at the side of the oesophagus, and after giving off two small vessels to the proboscis, enters the latter with the alimentary canal. Here it breaks up into a complicated series of branches supplying the

odontophore and the muscles. Two other prominent vessels (fig. 36) arise at the nerve collar, one on either side of the aorta. They both pass toward the tentacles but before reaching them, small vessels leave dorsally to supply the tissues of the "head" (fig. 36).

The right tentacular artery gives off at its origin a large branch in the male, the penis artery (fig. 36, *A. pen.*).

The Visceral Aorta (figs. 35, 36, *A. vis.*) can be seen quite distinctly without injecting. It turns abruptly after leaving the ventricle and runs close to the surface across the intestine. Half-way across it gives off a branch (figs. 35, 36, *A. g.*) on the right side, which passes to the stomach and breaks up into numerous twigs upon its external surface. The main trunk plunges into the mass of the digestive gland, immediately after crossing the intestine, and runs right through, to appear again at the surface on the other side. It now remains at the surface, just below the epithelium, and lying upon the digestive gland a little ventral to the edge of the gonad; and in this position runs to the end of the visceral mass. Branches are given off at intervals which run out at right angles to supply both the gonad and the digestive gland (fig. 36, *A. go.*).

THE VENOUS SYSTEM.

The blood which is carried to all parts of the body by the arteries, collects in lacunae and is brought back to certain more extensive central sinuses. Many of the paths which are taken are, however, so narrow and so well-marked that there almost appears to be a definite system of capillaries connecting up the arteries and veins. These channels are mere excavations, which may be lined

by a pseudo-epithelium due to modified cells. The centre of the venous sinus system is the region on the surface of the digestive gland at the back of the pericardium and underneath the renal organ (fig. 37). There is a large sinus—the largest in the body—underneath the pallial cavity (fig. 37), while an important vein runs along the right margin of the mucous gland (figs. 35 and 38, *R. Sin.*). These important regions may be named as follows:—The sinus in the anterior perivisceral cavity will be termed the *Cephalic Sinus* (fig. 37, *Ceph. Sin.*), as it collects blood from the head and foot. The branched system, situated at the back of the pericardium, and under the renal organ is the *Renal Sinus System* (fig. 37), while the long vessel-like sinus which extends from the right side of the renal organ to the anterior end of the mucous gland is the *Reno-Mucous vessel* (figs. 38 and 35, *R. sin.*).

Blood returning from the viscera (digestive gland and gonad) passes by means of superficial vessels (fig. 35) to a sinus which extends along the columellar surface of the visceral mass. This sinus stretches as far as the region of the pericardium and there becomes connected with the renal sinus system (fig. 37), by means of which the blood reaches the renal organ.

Blood returning from the head, proboscis, and foot flows into the great cephalic sinus (fig. 37, *Ceph. Sin.*), and from here two paths may be taken. These leave the perivisceral cavity at the posterior extremity of the mantle cavity, and are close together. One ascends and reaches the renal organ directly. It passes along its left side, internally, so that it cannot be seen unless the renal organ is turned back as in figure 37. The other receives blood from the oviduct and rectum (figs. 37, 38) and enters the Renal Sinus System and so to the renal organ.

THE RENAL BLOOD VESSELS.

It will be convenient now to discuss separately the vessels in the renal organ. This organ forms a junction system of small vessels which is interpolated into the venous system. The blood which enters it may leave by two paths, one of which goes to the heart directly and the other by way of the gills.

The blood vessels of the renal organ of *Buccinum* are remarkably organised. This, however, is probably general in the higher prosobranchiates. For purposes of comparison it will be advisable to use the renal organ of the Lamellibranch *Pecten*, which has been carefully worked out. In this genus the renal organ is a tube, the inner wall of which is thrown into folds in order to increase the area of renal epithelium. Between these folds are blood cavities. The blood leaves the renal organ by one path only and then passes to the gills.

In *Buccinum*, the renal organ is a similar tube, but it is crescentic in section and the inner wall of the outer half only is thrown into folds. The folds are quite different from those in *Pecten* (see Renal Organ below) and the floor of the renal organ (the unfolded side) covers a large vessel of the Renal Sinus System (fig. 37). The folds of renal epithelium hang down into the lumen of the renal organ, and from them membranous extensions pass to the floor. Now, on the floor, we have the large vessel of the Renal Sinus System, and from it vessels arise which pass *through the lumen of the renal organ* to the folds of renal epithelium.

Thus a large quantity of blood enters the renal organ over the internal surface. This is a most curious position which a glance at the diagrammatic section (fig. 51, A.) will make clear.

This, however, is not the only path for blood entering the renal organ. We have already seen that a large vessel runs round the margin (fig. 37, *lam. v.*). From this vessel branches arise which run across in the plane of the outer surface and divide up close to this surface. The system of anastomosing channels is extremely complicated, and minute, and finally all is resolved into two outgoing paths. One of these is seen right on the surface when the renal organ is injected, and is shown in fig. 35. It consists of delicate vessels running almost at right angles to the left margin (fig. 35). These delicate vessels enter a large lymph-like gland, the nephridial gland, which extends along the side of the renal organ against the pericardium. It was supposed that the nephridial gland communicated *only* with the auricle and that blood passed to it by means of the nephridio-cardiac vein and *back again* by the same course. A detailed study of this point in the whelk has clearly shown that there is a direct path from the renal organ through the nephridial gland to the heart. The other path is more internal and is made up of another series of small vessels which open into the *reno mucous vessel* running along the right side of the renal organ (fig. 38). Thus there are two lines of communication bringing blood to the renal organ and two paths along which blood leaves.

Blood Circulation in Pallial Complex.

The blood from the "kidney" which pours into the reno-mucous vessel passes forwards into that part of the latter bounding the mucous gland. Blood from the rectal region and mantle also enters this vessel, and from it passes through the mucous gland to the afferent branchial vessel. The mucous gland is exceptionally

well supplied with blood, as will be seen from figure 35. From the afferent branchial vessel a large number of filamental vessels arise which convey the blood through the gills to the efferent branchial vessel. The efferent branchial vessel collects some blood from the mantle which has passed through neither gills nor renal organ, but the quantity is small. Finally it enters the auricle.

To summarise:—

1. Blood passes from the ventricle to various parts of the system.

2. Blood is collected into sinuses and conducted to (*a*) Renal Organ, and (*b*) Gills.

3. The blood passes back to auricle through (*a*) Renal organ and gills, (*b*) Renal organ alone, (*c*) Gills alone, and (*d*) Mantle alone.

The largest quantity of blood passes through routes (*a*) and (*b*), and that passing by method (*d*) is almost negligible.

THE NERVOUS SYSTEM.

Once more we must emphasise the fact that we are dealing with an example of the most highly developed Prosobranchs. The Nervous System presents the twisted visceral loop characteristic of the Streptoneura, together with extreme concentration of the ganglia. So far as the description of the nervous system is concerned, constant reference has been made to the excellent work of Bouvier on the nervous system of the prosobranch gastropods. All the important details have been worked through again, however, and the figures differ in some minor details from those given in Bouvier's memoir.

Owing to the extreme concentration which has taken place, the nerve ganglia may be divided into two groups.

The anterior centres are situated in the cephalic region and surround the alimentary canal, forming a collar almost hidden by the salivary glands. The posterior centres lie just behind the pallial cavity in the region between that and the visceral mass. The two groups of ganglia are connected by the long visceral commissure (fig. 41, *vis. com.*). Dissection of the nervous system is a matter of some difficulty and is usually a stumbling block to some students. It is quite easy to find the nerve collar, but rather difficult to expose clearly the component parts owing to the presence of a tenacious fluffy connective tissue which obscures all.

The nerves and commissures passing into the body wall are also difficult to follow by reason of the toughness of their surroundings and their resemblance in colour to the tissues in which they are embedded.

It is best to dissect the nervous system in whelks that have been kept for a short time in alcohol. This hardens the muscle but brings out the nerves much more clearly. In addition, the action of a solution of oxalic acid is decidedly useful. It brings out the otocysts and clears up the muscular mass of the foot. In order to investigate the centres making up the nerve collar, it is best to cut through the cerebral commissure which lies above the oesophagus and then to dissect the alimentary canal carefully away. The ring of ganglia can be examined *from the inside*, and thus observed without requiring the removal of so much connective tissue.

The Anterior Centres are ten in number. They consist of the cerebral, pleural, pedal and buccal ganglia, which are paired and the supra- and sub-intestinal ganglia which have been drawn in, in the general concentration, until they have reached a position close to the pleural ganglia (fig. 42, *Sup. int.* and *Sub. int.*).

The Pedal Ganglia are the largest ganglia in the whelk and are situated most anteriorly. They are oval in shape and lie upon the floor of the perivisceral cavity, in close contact. Consequently there is no pedal commissure (fig. 42, *ped. g.*). In the female these ganglia are symmetrical, but owing to the origin of the large penis nerve from the right ganglion, in the male, they become asymmetrical (fig. 43). The pedal ganglia are connected to the cerebral and pleural ganglia on each side by two very short connectives (fig. 42, *c.p.*, *pl. p.*), a small space, the "triangle lateral," being left between the ganglia and their connectives (fig. 42, *tri. lat.*).

A large number of nerves arise from the anterior end of each pedal ganglion and run forwards together for a short distance to plunge into the muscular foot. These are the pedal nerves (figs. 41, 42, *ped. n.*) and they innervate the entire foot. Other smaller nerves leave the pedal ganglia on both the dorsal and ventral surfaces. According to Bouvier there are two such dorsal (fig. 42, *do.*) and three ventral nerves (fig. 42, *ve.*) from each ganglion. The former pass to the head region whilst the latter innervate both the foot in the immediate vicinity, and the floor of the anterior body cavity.

The penis nerves leave the right pedal ganglion at the posterior lateral corner (fig. 43, *P.*) and consist of two trunks, one of which is extremely large and follows the vas deferens inside the penis to form a network from which delicate branches innervate the muscles of the organ.

The Cerebral Ganglia will be seen somewhat out of their normal position if the dissection is conducted as described above, for after the severing of the commissure and the removal of the alimentary canal, they will be turned back as indicated in fig. 42, *c.*

They are somewhat irregular in shape and are connected with each other by a commissure which passes over the alimentary canal. Owing, however, to the folding of the gut and the almost vertical position of the oesophagus at this point, the cerebral commissure lies rather posteriorly to the gut. Both the oesophagus and branches of the anterior aorta are encircled by the collar formed by the cerebral ganglia, cerebral commissure, and pedal ganglia.

It will be noticed that the cerebral ganglia in the whelk are by no means the most anteriorly placed. They lie some little distance behind the pedal ganglia and almost directly above the pleural centres. This position, which may give rise to a little confusion at first, is due to the course taken by the oesophagus between the proboscis and the gland of Leiblein. The cerebral centres are joined by very short connectives to the pedal and pleural ganglia, and at this point it may be observed that there is a slight asymmetry in the relative position of the right and left ganglia. Two other small ganglia, the buccal (fig. 42, *bucc.*) are in close contact with the cerebral and are themselves connected by a long and delicate commissure passing in front of the alimentary canal.

Three nerves innervating the sense organs leave the external face of each cerebral ganglion. The largest of these is the tentacular nerve (fig. 42, *tent.*). It can be followed quite easily in the tentacles, and bends at right angles when above the ganglia to reach them. A few twigs are sent to the head region from this nerve before it finally penetrates the tentacle. The other two nerves pass directly, the one to the eye, and the other to the otocyst (fig. 42, *op. n.*, and *n. ot.*). The two otocysts are situated immediately below the anterior ends of the pedal ganglia and just imbedded in the muscular floor. They

are very easily overlooked, even when one examines the exact place where they occur. They are about two millimetres apart and 0.5 mm. in diameter.

In addition to these sensory nerves, there are two other groups which have their origin in the cerebral ganglia, i.e., the nerves of the proboscis and of the cephalic integument. The former arise just anterior to the cerebral commissure and form a compact bundle on each side, ascending with the salivary ducts and running along with them towards the proboscis. They innervate that organ and also the proboscis sheath. The cerebral nerves of the proboscis enter into close relation (forming anastomoses) with certain nerves from the small buccal

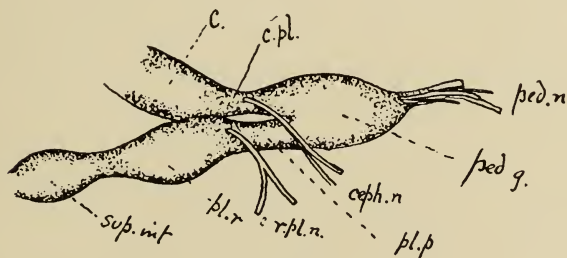


FIG. 6.

ganglia, and all pass together into the proboscis. The buccal nerves innervate the oesophagus and radular apparatus, the cerebral nerves on the other hand appear entirely concerned with the walls of the proboscis itself. There are two other nerves innervating the integument of the head region and these arise from the cerebro-pedal connectives (Text-fig. 6, *ceph. n.*). They eventually branch, sending numerous twigs to the region immediately posterior to the tentacles.

The Pleural Ganglia are asymmetrical owing to the positions taken by the supra- and sub-intestinal ganglia

(fig. 42, *sup. int.* and *sub. int.*) in the general concentration of nerve centres. They are attached to the cerebral and pedal ganglia by short connectives, the cerebro-pleural (fig. 42, *c. pl.*) and the pleuro-pedal respectively (fig. 42, *pl. p.*). The pleural ganglia form part of another nerve collar owing to the position of the sub-intestinal ganglion. This, normally attached to the left pleural ganglion, is here in addition fused to the right pleural so that it comes to lie between the two.

The left pleural ganglion gives origin to the siphon nerves (fig. 42, *Siph. n.*), the columellar nerve, and several others which innervate the body wall (fig. 42). The two siphon nerves pass outwards along the floor of the perivisceral cavity until the body wall is reached. They plunge through this tough muscular wall and arrive at the siphonal region of the mantle. A number of branches are given off to the siphon, and certain fibres form important connections with the pallial nerve from the supra-intestinal ganglion, eventually taking part in an anastomosis in the mantle (fig. 41). A left *zygoneury* is thus formed (fig. 41, *zyg.*).

The columellar nerve leaves the ganglion posteriorly and crosses over the floor of the anterior cavity towards the right side. It is not a very large nerve and is easily overlooked. Eventually it reaches the columellar muscle.

The remaining nerves are small with the exception of one which arises on the pleuro-pedal connective, divides soon, and innervates the walls of the body cavity.

The right pleural ganglion has only one nerve of importance here, and this corresponds to the last nerve mentioned above, arising from the left pleural ganglion. It takes its origin on the pleuro-pedal connective (Text-fig. 6, *r. pl. n.*) and innervates the right lateral walls of

the body cavity. The branches of this nerve are quite easily seen if the nerve collar *in situ* is pressed slightly over to the left side. The branches pass out directly to the right.

The Supra- and Sub-intestinal Ganglia. Three prominent nerves are easily seen crossing the floor of the anterior cavity and entering the wall on the right side. The most anterior of these is more delicate than the other two. All arise in the sub-intestinal ganglion (fig. 42, *sub. int.*). The two larger are the pallial nerves (figs. 41 and 42, *pall. n.*), and after plunging through the walls of the body cavity they reach and divide up on the mantle, the more anterior of the two forming an extensive network.

The branches of these pallial nerves of the right side come into contact with the branches of the left pallial nerves. This takes place in the mantle immediately above the pallial cavity. Thus a continuous network is formed running around the mantle edge.

A number of other small nerves (fig. 42) arise in the sub-intestinal ganglion and innervate the walls of the body cavity and the columellar muscle.

The largest nerve leaving the sub-intestinal ganglion arises from the left posterior corner. It is the Visceral Commissure itself (figs. 41 and 42, *Vis. com.*). This cord runs posteriorly almost in the middle line, in close contact with the floor of the body cavity, for some distance, and then passes underneath the most superficial muscle fibres. It is often very difficult to dissect out the visceral loop in the whelk, but if the specimens have been preserved in spirit, the track of the visceral commissure is visible as a delicate ridge on the floor of the body cavity running back from the point *x* in the figure.

The visceral ganglia are situated on the loop just

posterior to the mantle cavity. They can be seen from the exterior, without any dissection, under the epithelium of the area between mantle, digestive gland and columellar muscle. The other part of the visceral loop connecting the visceral ganglia with the supra-intestinal ganglion is by no means easy to follow, for it lies under the superficial muscles of the left wall of the body cavity. It leaves the wall near the point of entrance of the two left pallial nerves (figs. 41 and 42, *pall n.*"), and runs along with them to the supra-intestinal ganglion. The three nerves have thus to cross over the alimentary canal and gland of Leiblein. Of the usual figure of eight formed by the visceral commissure, only the lower, posterior, loop is of any extent.

The two large left pallial nerves arise in the supra-intestinal ganglion, and passing over to the left side, plunge through the body wall. They are extremely close together at first, and form one thick band. On reaching the mantle they proceed to divide. The most anterior nerve innervates the osphradium. In addition to this, it gives rise to some twigs which, by means of their anastomosis with the siphonal nerve, set up the zygoneural connection already mentioned as existing on the left side. Both the anterior and posterior pallial nerves from the supra-intestinal ganglion take part in the innervation of the gills.

An important nerve arises from the sub-intestinal part of the commissure itself, just at the posterior end of the perivisceral cavity. It runs outwards, underneath the vas deferens in the male (fig. 41, *com. n.*) to the rectum and mucous gland.

The **Visceral Ganglia** are two in number. Of these the right is much larger than the left, and gives origin to most of the nerves. The principal nerves are the

following:—The Visceral nerve (fig. 41, *visc.*) passes close to the left side of the vas deferens in the male and innervates the digestive gland and gonad. It is an extremely long nerve, in fact, the longest in the animal, and can be traced to the tip of the visceral mass. Two nerves, the recto-genital and rectal, (fig. 41, *rec.*' and *rec.*) pass out to the right, to the rectum and gonoducts. A larger nerve, the reno-cardiac (fig. 41, *r.c.*) passes out, breaking up very considerably on its way and sending a branch to the pericardium and heart. From the smaller ganglion a nerve arises which passes to the efferent branchial vessel (fig. 41, *eff.*).

THE SENSE ORGANS.

The sense organs may be divided into simple and compound, the former class including only the numerous sense cells which occur scattered amongst the ordinary epithelial cells, the latter the Eyes, Osphradium, and Otocysts.

THE EYE.

The eyes are two in number and are situated at the base of the tentacles, on the dorsal surface of a small lateral protuberance.

They are visible as two round intense black spots, but when the tentacle is contracted and the body wall is thrown into folds, the eye, hidden in the angle between tentacles and head, is not easily seen. No metallic glitter so characteristic of the Pecten eye ever occurs, and, as will be seen below, the layer in the eye responsible for this feature is not present.

The lowest gastropoda possess eyes which are simply sac-like invaginations of the outer epithelium. At the bottom of the sac the epithelium is modified somewhat

and forms the retina. The cavity remains open to the exterior.

In the higher gastropods the open pit is succeeded by a closed vesicle, and this ontogenetic sequence is probably an indication of the phylogeny. As we should expect therefore, the *Buccinum* eye is a closed vesicle cut off from the surface. The general epithelium extends over it, forming an outer cornea (fig. 47, *Cor.*). The wall of the vesicle is formed of a single layer of cells, once part of the bounding epithelium of the head. These cells are modified in various regions. The area immediately below the outer cornea, through which the light has to pass, is formed of cells free from pigment—the area itself is the inner cornea (fig. 47, *Ps. cor.*). The rest of the vesicle wall forms the retina and is made up of pigment-containing cells.

The cells of the outer cornea differ only from those of the epidermis in shape. As the optic vesicle is approached, the deep and narrow epidermal cells with slender nuclei become less deep and of greater thickness. There is a well-developed cuticular margin present. With this change there is an alteration in the form of the nucleus, a spherical shape taking the place of the slender compressed form. The optic vesicle is imbedded in a mass of connective tissue (fig. 47, *Con.*) and muscle fibres, in which numerous blood spaces occur irregularly. This tissue, which is usually more compact near the surface, is continued in so as to form a layer between the vesicle and the outer cornea.

The cells of the optic vesicle appear to be of two kinds, and only two kinds of cells make up the entire vesicle—retinal and corneal areas inclusive. In sections, the retina, or area directly opposite the cornea, is built up of very large cells, which can be distinctly

seen extending from the connective tissue to the cavity of the eye (fig. 47, *Ret. c.*). They possess spherical nuclei in which may be seen a nucleolus and numerous granules, and their distal portions are lost in a mass of dense black pigment.

Between these large cells are to be found a number of compressed nuclei (fig. 47, *Nuc. int. C.*), which stain more darkly than those above mentioned, possess finer granules, and in short cannot be mistaken for the nuclei of the large cells. These nuclei belong to slender fusiform cells which are interpolated between the larger ones and whose boundaries are difficult to follow in sections. If the eyes are macerated in a 4 per cent. cocaine solution in seawater, the true shape of the structures building up the retina becomes at once apparent. The large cells possess the extraordinary shapes indicated in fig. 48. It will be noticed that they are widest towards the base, and that the nucleus is in general situated not far from that region, in fact, somewhere near the centre of the cell. One of the most curious facts is the prolongation of the cell into processes, of which there may be several (fig. 48, *pr.*). The apex of the cell is rounded and contains a large quantity of black pigment (fig. 48, *Pig.*) in the form of minute granules closely crowded together. Very often, too, this rounded distal extremity bears a prominence which may be taken as the remains of the "Stiftchen" or hair-like processes seen in sections and mentioned below. The narrow cells also possess pigment, so that there is no differentiation here into pigmented and pigmentless cells.

The cavity of the optic vesicle is filled with a structureless gelatinous mass, which forms a lens (fig. 47, *Lens*). This lens does not possess a perfectly rounded contour where it abuts on the retinal cells, but is indented

and in each indentation there is a delicate bundle of hair-like "Stiftchen" (fig. 47, *St. s.*), which appear to break away from the cells in macerations. Thus the eye of *Buccinum* agrees with the long series of eyes possessing Stiftchen-bearing cells. The presence of such processes is one of the most striking characters in the structure of visual organs.

There has been no small difference of opinion as to which are the visual cells in gastropod eyes. In many cases the difference between the cells which has struck the observer has been the presence or absence of pigment. Here both sets possess pigment. Could the actual nerve connections be demonstrated, the matter would be easily solved, but unfortunately the fibrous processes of both cells merge into the tangled mass of nerve fibres and connective tissue below the eye. Judging from structures in the eye of *Pecten*, and especially from the character of the nucleus, the author would say that the large cells are the visual cells notwithstanding the fact that the cell body of the slender cells is more in accordance with expectations.

This view is, however, supported further by two facts. The large cells appear to possess the "Stiftchen." Both kinds of cells occur laterally almost up to the inner cornea. There the large cells begin to disappear, whilst the nuclei of the others are very like, one might almost say the same as, those found in the cells of the inner cornea itself. According to this view, therefore, the slender cells are merely supporting cells, and they are continued across the eye to form the inner cornea.

The nuclei of the inner corneal cells are flat compressed structures (fig. 47, *Ps. cor.*), like the nuclei in the retina, but instead of being arranged at right angles to the wall of the cavity they have rotated, so

that they now lie end to end and parallel with the plane of the cornea. The gelatinous lens is probably secreted by the supporting cells. The optic nerve breaks up underneath the optic vesicle, and a network of fibres extends below the retina.

So far as observations go, the whelk relies but little on its visual organs. It is difficult to understand how complicated organs of this kind could be produced in the mollusca, when one thinks of the feeble responses to experiments. Either our experimental methods have failed so far to demonstrate the utility of many of the molluscan eyes, or some of our conceptions of evolutionary processes require modification. The tendency to take anthropomorphic views, however, in work both structural and experimental, for invertebrate sense organs is perhaps the danger to be avoided.

THE OSPHRADIUM.

The sense organ known as the Osphradium, situated usually in close proximity to the respiratory organs, attains a degree of complexity in *Buccinum* which is probably never exceeded in the Mollusca. In the Lamellibranchs the osphradium is merely an area of somewhat thicker epithelium, whose presence is not even marked by pigment (except in *Arca*). It is, therefore, quite invisible to the naked eye.

The lower gastropods, the Diotocardia, possess an osphradium which seems to be somewhat of the same type so far as general structure is concerned. As one passes, however, towards the more highly developed Monotocardia, the osphradium takes the form of an axis bearing on each side a large number of leaflets. It becomes, in fact, bi-pectinate, and resembles superficially a gill.

The osphradium of *Buccinum* is usually obvious as soon as the shell is removed, for it can be seen through the mantle. There is no difficulty in finding it when the mantle cavity is opened and the roof examined. It stands out as a deep brown-black organ, situated right across the gutter of the pallial siphon and between this organ and the gill (fig. 8, *Osph.*). It lies, therefore, on the opposite side of the ctenidial axis, and by reason of its build was formerly known as the "false gill." It is long, and is made up of about 90-100 leaflets arranged on both sides of an axis, which is nothing but an elongated nerve ganglion covered by epithelium. These leaflets are largest in the centre and diminish in size towards the ends, giving the whole the appearance of an elongated oval. The leaflets are roughly triangular in shape, those of the right or ctenidial side being, however, larger than those of the left (fig. 44). Each leaflet has an inferior free edge (fig. 44, *Inf.*), a lateral edge (fig. 44, *Lat.*), and what must be termed the third side of the triangle—the internal edge—which is curved and fused to both mantle and nerve axis (fig. 44, *Pall* and *N. ax.*).

The entire surface of the lateral faces is pigmented, but the pigment is often free from the inferior edges of the leaflets, a condition the reverse of that described by Bernard for *Cassidaria*. For a further study of the organ reference must be made to sections.

Each Oosphradial leaflet is a fold of the epithelial layer bounding the inner surface of the mantle, together with certain connective supporting tissues. Just as in the branchial leaflets, there is an external bounding epithelium resting upon supporting membranes and leaving a series of flat blood spaces, which are here occupied largely by branches of the osphradial nerves (fig. 45). The epithelium resembles

that of the ctenidial leaflets further in being modified and specialised in different regions. These regions are (a) sensory, (b) glandular, (c) ciliated, the former being by far the largest in extent. The sensory region extends over the greater part of the free lateral surface of the leaflets. The glandular region is confined more or less to the edges, and in particular to the lateral edges (fig. 44, *Osp. gl.*). The ciliated area is a long narrow strip extending along both sides of the leaflet against the glandular edge and between it and the sensory area (fig. 44, *Osp. cil.*). Thus in a section taken through A-B (fig. 44), the glandular area is nearest B, that is where the free lateral edge meets the mantle, this is followed by the ciliated region, and then the remainder is sensory. The sensory area is characterised as in the lamellibranchiata by an absence of cilia, and a considerable thickening of the epithelium. This thickening is due to an increase in the length of the cells, which are further modified by the possession of a yellow granular pigment. Now the real structure of this important area is not easily investigated. Sections well preserved and fixed show that it is built up of a large number of pigment-bearing cells, whose nuclei are apparently arranged at different levels because one sees nuclei close to the basal membrane, and from here to near the free surface they are irregularly scattered (fig. 45, *Osp. so.*). There is, however, a stratum close to the free margin of the cells perfectly free from nuclei, and it is here that the pigment is situated.

Macerations of the osphradium explain the structure instantly. The pigment-bearing cells are of the type indicated in fig. 46, and all agree in possessing a terminal plateau in which the pigment lies. From this plateau the cell becomes constricted and fibre-like, with, however,

one large swelling where the nucleus lies. The position of the nucleus varies considerably, and so it is possible to pack together many more cells than would be the case if the nuclei were all situated at the same level.

These cells are the indifferent cells of Bernard. One feature that he has overlooked is the well-defined cuticular margin (in sections), crossed by delicate striae arranged perpendicularly to the free surface of the epithelium.

Now, in addition to these cells, there are, according to Bernard, neuro-epithelial cells which are in connection with the nerve fibres. These neuro-epithelial cells are always fusiform and possess a rounded or oval nucleus. If the osphradium is an important sense organ (and one would assume so from the size of the nerves innervating each leaflet, as well as from the great central ganglion), and if the nerve endings are neuro-epithelial cells we should expect the latter to be numerous and fairly obvious. The contrary is, however, the case, and in ordinary sections it is hardly possible to make out many cells of a different type from the pigment cells already described.

Are the nerve endings different, then, from those described by Bernard? The osphradium of the gastropoda appears to be homologous with that of the lamellibranchiata, and so far as general structure is concerned there is perfect agreement. List has shown that in *Mytilus* there are free nerve endings in this organ, and the author of this memoir has seen and described the same structures in *Pholas* and *Pecten*. Furthermore, Gilchrist has described free nerve endings in *Aplysia*.

The most striking similarity in the microscopic structure of the organ in lamellibranchs and the whelk is evident, and the description of the lamellibranch osphradium might be used for that of the whelk. For

example, List states that "the neurofibrillae split in the epithelium into several branches, form richly branched networks, and send some fibrillae through the cuticle to the outside. Since, however, every fibril does not pass beyond the cuticle, but often only goes as far as its outer edge, one can easily get the impression that the osphradial epithelium was ciliated with very delicate cilia which have partly fallen away in fixation." This pseudo-ciliated margin is, then, the cuticle with its numerous neurofibrillae.

Bernard merely states that there is an inter-epithelial network of nerve fibrils, and leaves one to assume that these are all connected with neuro-epithelial cells. The real case is as follows:—Below the epithelium runs the nerve, and with the nerve fibres are multipolar ganglion cells. From these multipolar cells delicate neurofibrillae pass out and enter the epithelial region. Here they branch in all directions and finally reach the surface. They run through the cuticular seam in a parallel manner perpendicular to the plane of the epithelium and appear, therefore, as striae in sections.

So far, Ranvier's gold methods have not been used, and Bernard's neuro-epithelial cells have not been actually re-investigated by the methods he used. The nerve network with the free nerve endings is, however, present and is without doubt the important sensory structure in the organ. By ordinary methods and macerations no obvious or numerous sense cells were found. The structure is, in my opinion, identical with that of the lamellibranch osphradium.

Little need be said about the non-sensory epithelium of the leaflets. The ciliated band (fig. 45, *Osp. cil.*) is about ten cells broad, the cells differ from those of the sensory area in being compact, more cylindrical, and with

deeper-staining contents. Bernard is in error in saying they possess no pigment.

Underlying the epithelium of the osphradial leaflets is a delicate basement membrane and a connective tissue layer with prominent muscle fibres. The centre of the leaflet is occupied by irregular blood spaces, which communicate with a very definite sinus running down the external margin.

The nerves of the osphradial leaflets are derived from a central ganglion, situated along the axis of the organ. This ganglion consists of a central mass of fibrillae, the neuropil, with the usual cortex of ganglion cells. The ganglion cells occur, therefore, on all sides, but are, nevertheless, more concentrated laterally, except where nerves are given off to the leaflets.

To each leaflet a nerve is given off, and this leaves the side of the ganglion exactly halfway down. This principal leaflet nerve runs outwards across the leaflet, nearer the inferior border than the opposite and attached edge (fig. 44, *Os. n.*). It gives off numerous branches on both sides, but particularly on that towards the mantle. These latter branches are very regularly arranged, and from them arise the neuro-fibrillae which enter the epithelium to form the nerve-net already described.

THE OTOCYSTS.

The otocysts are spherical sacs formed of a delicate epithelium. The cells are low and irregular in shape with but little contents. Two types are present, sense cells and non-sensory cells.

The depth of cells is only $\frac{1}{22}$ of the diameter of the otocyst. The large cavity is filled with calcareous matter forming an otolith.

THE RENAL ORGAN.

The renal organ, the so-called "nephridium," is visible at a glance when the shell is removed. It occupies a position immediately behind the pallial cavity, on the right side of the pericardium above the digestive gland and rectum. The renal organ of *Buccinum* is not only one of the most highly developed in the Prosobranchiata, but one of the most complicated in the Mollusca. Fundamentally, it is a sac communicating with the pallial cavity and the pericardium. The wall of this sac performs a special function—that of renal excretion, but under no circumstances does the blood system open to the external world in this organ. Externally the sac is covered by the general integument of the body. The outer and inner walls of the renal organ, that is to say, the former underlying the integument and the latter resting upon the digestive gland, are entirely different in appearance. The epithelium of the outer wall is prolonged into filaments or processes of various shapes, which are held together in such a way as to form ridges projecting into and occluding the lumen of the organ (fig. 49). In addition to this epithelium, which is the true glandular layer, there is a supporting connective tissue layer. The other walls are merely a delicate transparent epithelium. The renal organ should be opened by making an incision along the right side close to the digestive gland. The internal surfaces can then be examined.

It will be noticed, however, without any dissection that another structure is present, lying close to the glandular renal organ proper and forming part of the walls of the sac. This forms a band about $\frac{1}{8}$ inch wide between the pericardium and the renal tissue. It differs

from the latter in texture and also somewhat in colour. It is to a large extent quite independent of the renal organ and has been termed the Nephridial Gland (fig. 49, *neph. gl.*, fig. 50). Seen from the cavity of the renal organ, the nephridial gland differs altogether from the glandular wall of the former. Instead of ridges formed of numerous conical and other filaments, the surface appears as if it were made up of branched and anastomosing fibres, which generally run transversely to the long axis of the gland and renal organ.

If a solution of methylene green or säuresfuchsin is injected into the foot, one finds after a few hours that the renal organ is taking up the substance from the blood and is deeply coloured by the dye. The nephridial gland, however, is quite free from stain. A second feature of importance is that the nephridial gland is interpolated into the circulation between the renal organ and the auricle, and any injection mass forced into the efferent branchial vessel passes very easily into this gland after filling the auricle. In fact, the nephridial gland is a large spongy blood lacuna.

The Renal Aperture.—The external opening of the renal organ is situated on the anterior wall separating the gland from the pallial cavity. It lies slightly above and to the *left* of the rectum. It is a fairly conspicuous opening, slit-like, and of about 3 mm. in length. The long axis of the opening runs dorso-ventrally. The lips of the aperture are thickened owing to the development of muscle fibres, which form a sphincter muscle. The opening leads directly into the lumen of the renal organ, which is only separated from the pallial cavity by the membrane above mentioned.

The Reno-pericardial Aperture.—This opening is not situated at the most posterior part of the gland but

laterally, on the inner wall of the pericardium, and some distance away from the main cavity of the renal organ. The opening is much smaller than the external renal aperture and often difficult to find, though it is rendered more conspicuous by the somewhat white lips standing out on the darker background of membrane. It is not easy to see what may be the use of the reno-pericardial canal and opening. In those molluscs in which a pericardial gland is present as an accessory excretory organ, the products, of course, would pass to the exterior by this canal. Pericardial glands are, however, not widely distributed in the gastropoda, and appear entirely absent in the whelk.

Structure of the Renal Organ.

In considering the vascular system of the whelk, reference has already been made to the large sinus which lies under the floor of the renal organ. From this sinus a number of vessels arise, which, after crossing the lumen of the nephridium, give rise to branches which pass to the filaments of the ridges (fig. 49, *ren. r.*). Each filament is an evagination of renal epithelium, and each contains a blood cavity. The cells of this epithelium are of two kinds, glandular and ciliated, but the former are by far the most numerous. The ciliated cells occur on the summits of the filaments (fig. 52, *ren. cil.*) and pass gradually into the gland cells. The gland cells are regular columnar cells, the height not greatly exceeding the width. The cytoplasm is very regularly vacuolated, and remains as a kind of fine network in the cells, staining reddish violet with methyl-blue-eosin. Very large vacuoles are not usually present. The nucleus is situated at the base of the cell. Underlying both kinds of cells is the continuous supporting membrane of connective tissue

in which occur scattered muscle fibres (fig. 52). The blood spaces are extremely narrow but can be traced very easily after staining with methyl-blue-eosin (Mann). Every now and then one meets with sections of the vessels which occur on the ridges (see vascular system for further details of circulation in renal organ.) The ridges considered above belong to what has been termed by Perrier the "*principal system*."

Running round the left side of the renal organ proper, between it and the nephridial gland, is a membranous flap ending in a smooth transparent edge (figs. 49 and 51, *ren. lam.*). It is continued, though very much smaller in size, along the posterior margin. From this lamella a number of secondary lamellae arise and run at right angles attached to the wall of the renal organ between the ridges already discussed. These little partitions (fig. 51, *lam. pr.*) are hidden by the ridges, but can be seen quite distinctly if the latter are just pulled aside. In order to examine the structures further it will be necessary to macerate the gland—and to remove the glandular filaments entirely.

It will then be seen that the secondary lamellae give off in their turn tertiary lateral lamellae, which finally divide up into very delicate branches (fig. 51, *lam. S.*). This secondary system does not appear to play any great part in the rôle of excretion. It seems to be confined to the highest prosobranchs, and Perrier regards the two systems as equivalent to the two lobes of the renal organ of the Volutidae. The histological structure of these lamellae is very different from that of the filaments. In section they are of considerable thickness. There is the same bounding layer of glandular cells, but they are more cubical than columnar. The greater part of the structure

is filled by a mass of cells whose boundaries and nuclei are often quite difficult to make out (fig. 53). The reason is that the cells are filled with refringent granules (fig. 53, *C. gr.*), possessing great affinity for eosin stains. These granules when stained mask the nuclei. Under low powers of the microscope the substance of the lamellae looks therefore like a granular or even fibrous mass of connective tissue. In places, cells occur possessing none of these peculiar contents, and as a result cell boundaries and nuclei are easily determined, and the whole looks like an island of cells (fig. 53, *C. r.*) in the midst of the dense staining mass. In many cases it actually appears as if the granules were first developed *in* the nuclei.

Finally, one finds blood lacunae occurring amidst the mass of cells as in the filaments.

NEPHRIDIAL GLAND.

The structure of the nephridial gland is exceedingly interesting. It is composed of a somewhat compact lymphoid tissue, a fibrous groundwork with numerous lymph cells. Everywhere blood lacunae are to be seen. The most striking feature, however, is the presence of long canals, evaginations of the wall of the renal organ, which extend into the nephridial gland and end blindly. Sometimes the canals branch slightly before terminating. The canals are about $\frac{1}{12}$ mm. in diameter and are lined by ciliated cells. There is no trace of any opening between the nephridial gland and the lumen of the renal organ. The function of the nephridial gland does not appear to have been satisfactorily ascertained. This kind of statement recurs too frequently in descriptions of invertebrate structures. The injections made in the course of this work give only the negative result that the gland is not excretory like the renal organ. The experiments were,

however, neither numerous nor detailed enough to allow of a really definite statement being made. On the other hand, the intimate relation between the nephridial gland and the vascular system implies some function connected with the composition of the blood. Perrier discusses two theories, the first that it may be an organ for reserve matter, the second that it is concerned in the formation of blood. The author of this memoir is inclined to believe that the gland is a lymph organ with some additional function: further work is being carried out on the subject.

The morphological value of this gland is another point of considerable interest, particularly in connection with the attempts made to discover a homologue in the Monotocardia of the second renal organ of the Diotocardia, or to determine which renal organ, if any, has gone from the Monotocardia. Originally it was supposed that the renal organ present in the whelk represented the right nephridium of the Diotocardia. Perrier took this view, and starting from the fact that in *Patella* both organs are present and both are situated to the right of the pericardium, he pointed out the resemblance in position of the nephridial gland and renal organ in such forms as *Buccinum*. His theory, in short, was that the two renal cavities of the lower gastropods had fused, and the left renal organ had passed to the right of the pericardium. Then the right organ had kept its true primary function of excretion, whilst the left became the nephridial gland by development in its walls of tissue with a new function. As further proof of this view, the intermediate forms—*Haliotis*, *Turbo*, and *Trochus*—are brought forward, in which, whilst both renal organs are still present, the left has almost lost its function of excretion.

Against this we have the fact that the renal aperture

of the Monotocardia lies to the *left* side of the rectum, and embryological evidence supports strongly the view that the "kidney" of the whelk represents the *left* renal organ of the Diotocardia. This conclusion seems at present to be the most probable, and though in *Patella* it is the left kidney that is reduced, the Docoglossa can hardly be considered as on or near the line of evolution of the Monotocardia.

REPRODUCTIVE ORGANS.

Under this heading will be considered:—(1) the Gonads, (2) the Gonoducts, and (3) the organs of copulation. The sexes are separate in *Buccinum*, as in most prosobranchiate molluscs, and the difference is well marked externally owing to the male possessing a large penis which lies folded back in the mantle cavity. The gonoducts are well differentiated and quite separate from the renal organ, having their own openings to the exterior.

The Male Gonad (fig. 54, *Go.*), which resembles the female in shape, size and appearance generally, is situated upon the digestive gland and in close contact with it. Both are in fact covered by the same membrane forming the integument. The testis extends from the cleft marking the point of contact of the two lobes of the digestive gland, along the right side up to the very tip of the spire (fig. 54). By reason of its more or less bright yellow colour it stands out markedly against the dark coloured tissue of the digestive gland. Slightly ventral to the gonad on the right side, and on the surface of the so-called "liver," so that it is visible to the eye without any dissection whatever, runs the male duct, the vas deferens (fig. 54, *V. def.*). It is at first very narrow, but gradually increases in thickness as it approaches the

region of the stomach. During all this length it receives branches from the gonad and is coiled and folded in a very characteristic manner. These convolutions become more complex as the vas deferens passes forwards, and finally it forms a tubular storing chamber in the region between gonad and renal organ (fig. 54, *V. def.*!). The actual length of the vas deferens is several times the distance from the tip of the spire to the end of that duct in a straight line. After the convolutions the vas deferens becomes again somewhat reduced in diameter and, with fewer folds, passes forwards towards the thickened body wall of the "neck" region. Just upon reaching the pallial cavity, it turns in a spiral manner—this part being again of somewhat greater diameter—and then runs directly to the base of the penis under the body wall, which forms the floor of the body cavity.

The Penis is a permanent organ of very considerable size, which arises somewhat on the right side of the neck (fig. 54, *Pen.*). It is spatula-shaped, flattened, and broadest at the distal extremity. Though capable of some contraction, this tough muscular extension of the body is so long that it would protrude from the shell were it not for the fact that normally it is bent back and lies hidden in the mantle cavity. A little distance from the end there is a small tentacle at the apex of which the vas deferens opens. The vas deferens, however, does not run directly through the penis. It winds on itself in a spiral fashion, running through a tunnel from the base of the organ to its aperture on the tentacle. The male organs, it will be seen, are comparatively simple, and no accessory structures are connected with the vas deferens. In some gastropods the penis has been found to undergo seasonal variation in size—no trace of this has been noticed in *Buccinum*.

Sections through the testis show a tubular structure, the tubes opening into one another until finally a small duct is formed which joins others and makes up the canal opening into the vas deferens. In the ripe testis the germinal epithelium, which forms the wall of these tubes, gives rise to spermatocytes, which break away and fill up the marginal area of the cavity (fig. 56). Nearer the centre of the cavity are numerous smaller cells, the products of division of the spermatocytes, and themselves the spermatids (fig. 56, *Sptd.*). Both spermatocytes and spermatids are characterised by the small quantity of cytoplasm and the densely-stained nuclei. Complete series of stages in spermatogenesis may thus be seen, but the bodies formed are not of such a size as to make observation easy. The nucleus of the spermatid gradually elongates and becomes more attenuated to form the head of the spermatozoon.

Retzius was the first to discover two kinds of spermatozoa in the whelk. The presence of two kinds of spermatozoa in the gastropoda was noticed so far back as 1875 by Schenk in *Murex*. Since then the double character has been recognised in several species of Prosobranchs. The two different forms have been designated by the names "hair-like" and "worm-like." The former are long fibres with an extremely long head, almost half the length of the sperm (fig. 57, *b.*). In ordinary stained preparations these will be probably the only sperms recognised, and the only differentiation will be into the long narrow head and tail. At the anterior end of the head is a small, clear, vesicular cap. From this point a central fibre is visible running down to the base of the head. Very often in fixation this contracts so as to throw the head into a spiral. A middle piece follows the head, but is of the same diameter. The tail

is also of the same diameter and retains this until the pointed extremity is reached.

The "worm-like" spermatozoa (fig. 57, *c.*) are rather wider and shorter than the "hair-like," and the region of greatest diameter is near the anterior end. No differentiation can be made out except that the cytoplasm possesses a number of granules. Retzius states, however, that in macerated preparations a long fibre can be seen running down one side from end to end.

The vas deferens is lined by ciliated cells, and in the reproducing season is filled with spermatozoa, any cut causing a white milk-like fluid to ooze out.

The Female Gonad occupies the same position as that of the male, and running along its right and ventral side is the oviduct, which lies in very much the same position as the vas deferens in the male, and begins by being an extremely small canal. It is very different, however, from the male duct in being perfectly straight without the peculiar windings (fig. 55, *Ovd.*'), which seem to be characteristic of the male gonoducts. One meets with the same convoluted vas deferens in other groups of animals. It is probably due to the fact that development of the spermatozoa takes place after the spermatocytes have been cut off from the epithelium, and also to the absence of any large storing organ for the spermatozoa. The oviduct is a narrow tube with delicate walls. In fact, it resembles a large blood vessel, running along the right side of the digestive gland close to the surface (fig. 55, *Ovd.*'). At a point below the renal organ, it turns abruptly at right angles, and immediately takes on a very different structure (fig. 55, *Ovd.*"'). The walls at once increase in thickness until the tube forms a cylinder about $\frac{1}{2}$ an inch in diameter. The walls of this are, right and left, about $\frac{1}{4}$ inch thick, and the lumen in section is a long crescentic

slit running dorso-ventrally. These walls are perfectly white and of a very peculiar cheese-like consistency. This posterior glandular portion of the oviduct, after its abrupt beginning, takes again the anterior direction, and runs along to the right of the rectum, the rectum, in fact, lying upon it (fig. 59). It eventually opens by a small orifice into the pallial cavity.

The ovary is also tubular in section, the wide tubules of which it is composed being arranged at right angles to the surface of the gonad. In a hand section the parallel arrangement of ovarian tubules may be distinguished quite easily with the naked eye. In transverse section they are five or six-sided (fig. 60), and are composed of a thin wall of germinal epithelium (fig. 60, *Ge. ep.*)—flattened cells—which here and there gives rise to large egg cells. These contain a conspicuous nucleus with nucleolus. One interesting fact is that the germinal epithelium gives rise to delicate follicles of flattened cells, which surround the developing eggs (fig. 60, *Foll. ep.*). This is seen again in the Cephalopoda, but does not seem to be the rule in the Lamellibranchiata. It is certainly not so in *Pecten* or *Cyclas*, where the stalked egg projects freely into the cavity, surrounded only by the egg membrane.

EMBRYOLOGY.

Fertilisation takes place internally, but details of the exact procedure have so far not been observed. The eggs, surrounded by a transparent viscous mass of albumen, are laid in capsules which are deposited in considerable numbers attached to each other, and often fixed to floating objects or to mollusc shells, rocks, crustacea, etc., on the sea bottom. Whelks' egg-capsules

form one of the most familiar objects of the flotsam and jetsam thrown up on our shores.

The individual capsules are flattened on the under side, and when seen from above they are oval in shape. A clearer idea of their appearance can be best obtained by reference to the figures. The wall is made of two layers of membrane, both of which are perfectly smooth on the ventral flattened side (fig. 61). The outer wall appears crinkled on the convex surface (fig. 65). This is due to the presence of delicate fibres, which, however, are of short length and often branch.

The outer walls of adjacent capsules are continuous, so as to join the yellow capsules together in masses.

The eggs of the gastropoda are not always laid in chitinous capsules of this kind, there being other modes, i.e. (*a*) free without any protecting capsule, (*b*) with calcified membrane, (*c*) deposited in ribbons (*Opisthobranchs*), and (*d*) in gelatinous masses. The capsules of the whelk have been supposed by most zoologists to be formed by the oviduct, and the most distal or uterine portion of that tube is extremely glandular. Cunningham, however, in 1899, in a letter to "Nature," announced that the egg capsules of *Buccinum* and *Murex* were formed by a secretion from the anterior groove of the foot. The eggs must therefore pass round from the pallial cavity, imbedded in a quantity of gelatinous material, to the under surface of the foot. Then in the groove they become surrounded by the chitinous capsule. Cunningham's discovery has apparently never been noticed, and no information on the subject appears in the textbooks. Not only does *Buccinum* form its egg capsules in this way, but the same thing applies to *Purpura*, and Pelseneer has actually found the capsules in the ventral pedal gland.

The exact number of eggs placed in the capsules also seems to have been overlooked by most workers. Koren and Danielssen, who give the largest numbers, say that variations from 6 to 800 occur in *Buccinum undatum*. Our counts have given from 49 up to 2,419! Moreover, the high numbers were by far the most common. Few capsules contained less than several hundred eggs. In what must be regarded as a very small clump of egg capsules (about 2 cub. inches) we calculated that there must be about 200,000 eggs.

It is a well-known fact that the number of young whelks leaving the capsules is very much smaller than the number of eggs placed therein. Here again, the figures vary, but the average is probably somewhere around the figure 10. Each capsule is penetrated by a small oval hole, which appears always in the same place, near one margin of the flat side (fig. 61).

The eggs are 0.25 mm. in diameter, the young shells at the time of leaving the capsules are 3 mm. from the tip of the spire to the end of the siphon, and three whorls are present of rapidly increasing size.

The embryology of the whelk must be left for a separate work, any consideration of it in a detailed manner would be beyond the usual limits of a memoir of this kind. Koren and Danielssen, in the "Fauna littoralis Norvegiae," were probably the first to describe the sequence of events taking place in the egg capsules. Their account is extremely interesting, though the treatment was naturally limited by lack of the methods now available for embryological research. The eggs when laid are imbedded in a perfectly transparent viscous mass. As development takes place, this albumen becomes less and less viscous, and the eggs become crowded together. Now, according to Koren and

Danielssen, little groups of eggs, containing from 30-60, sometimes even 130 individuals, separate out, and around them a delicate granular mass appears—a supposed exudation from the eggs. Each little group of eggs becomes an embryo, and the granular mass takes on the form of a definite limiting membrane, which gives later the shape of the larva.

What really happens, however, is the much more probable sequence observed first by Carpenter in *Purpura lapillus*. According to this investigator, only a few of the eggs in a capsule are to be looked upon as true ova. The remainder are termed “yolk spherules.” The distinction between the two is manifested at the time of the first segmentation, the yolk spherules dividing into two equal hemispheres, the real ova into a larger and smaller segment. Segmentation of both takes place, however, and it should be interesting to determine whether this is due to an actual difference in the eggs laid or to fertilisation by the different kinds of spermatozoa now known to exist. As the embryos develop they commence actually to *swallow* the segmented yolk spherules, and it is these carnivorous embryos which Koren and Danielssen took to be clusters of eggs with an exuded membrane.

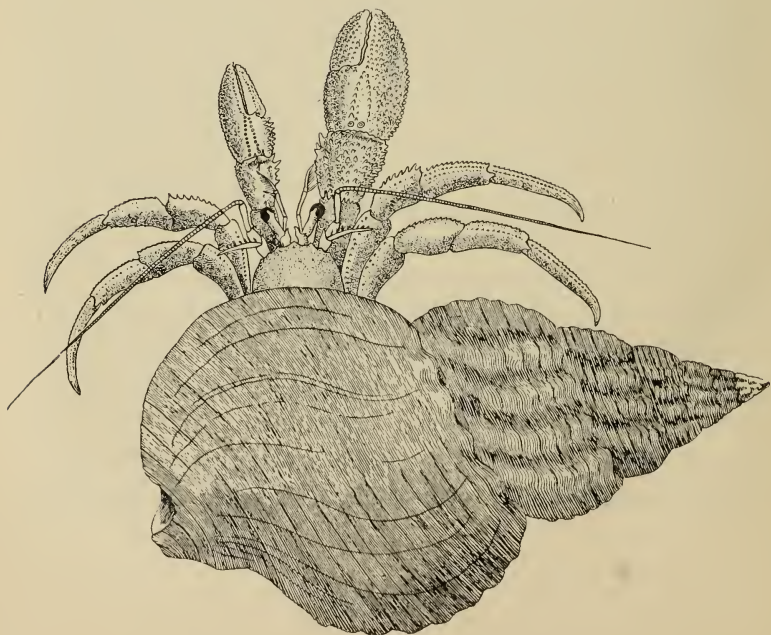
Bobretzky describes in some greater detail the embryology of a gastropod supposed to be *Fusus* (sp. ?) Whilst, however, he gives in his account a description of the formation of blastula, gastrula, and early embryonic stages, he does not make any mention of the carnivorous act, and his egg capsules only contained 7-20 eggs! The egg divides into two similar halves, and then into four large cells by a second division. These four large cells cut off four small ones which lie close together. Four other small cells follow these, being

cut off in a similar manner, and then by division of the first four small cells a total number of twelve is reached. By the segmentation of the small cells themselves, and by the addition of others a layer of cells (ectoderm) is formed which gradually grows round the egg until a space is left at the opposite pole. Here the four large cells remain visible and form part of the wall of what may be termed a blastula. The gastrula is formed by the depression or invagination (very slight) of the large cells, and the growth of the ectoderm at the blastopore. The further details of this development do not actually apply to *Buccinum*. This, however, gives one a hint of the processes by which the early carnivorous stage is formed. As soon as stomach and oesophagus are developed, the embryo starts devouring the eggs in the capsule.

The ectoderm is ciliated, and outlines of head and foot are soon to be observed. The otocysts are visible very early, and are closely followed by the eyes. At this stage the embryo is quite symmetrical. The stage shown in fig. 64 on Pl. VIII, represents a fully developed embryo some time before the shell and body attains the size which may be termed the "young whelk" stage, at which it leaves the capsule. At this period the head is well developed, and eyes and tentacles are obvious structures. The velum (fig. 64), in the form of a bilobed structure fringed with particularly large cilia, has reached its maximum development, and by that means the larva moves actively round in the capsule. The foot (fig. 64) is well developed—the pedal groove (*Ped. gl.*) being relatively large, and the otocysts can still be seen, though they have sunk away from the epithelium and lie quite deep in the body. The larval shell is also conspicuous. It is a very delicate chitin-like structure, not yet coiled in a spiral, and marked by delicate

longitudinal ridges. One very curious organ must also be mentioned. Protruding slightly from the pallial cavity is a vesicle (fig. 64, *Pul.*), which is apparently an evagination from the floor of the cavity. This vesicle contracts rhythmically. It has been noticed in other larval gastropods and termed the "larval heart." It is not, however, to be regarded as an early stage in the development of the true heart, which is situated much further back.

Further development results in the absorption of the velum, increase in size, and spiral coiling of the now asymmetrical shell. Of the thousand eggs that might have been in the capsule, perhaps ten may eventually reach the stage, of which the shell is figured on Pl. VIII. This reduction is due in the first place to the small number of eggs that can develop into young embryos, and secondly to the cannibalism exhibited by those same embryos practically as soon as the first rudiments of an alimentary canal are developed.



APPENDIX

DISTRIBUTION AND ECONOMICS.

The genus *Buccinum* is widely distributed in Arctic, Antarctic and Temperate zones. The species *Buccinum undatum*, Linn., occurs all around our coasts, from low-water mark to 100 fathoms, and over a considerable area extending from the Atlantic coast of North America to the Siberian seas. The genus appeared first in the Jurassic rocks, the species *B. undatum* occurring in the Coralline Crag, since when it seems to have become increasingly abundant in our seas. The Common Whelk, *B. undatum*, is the most abundant species and the most convenient to examine as a type of the genus. It inhabits different kinds of ground, and several marked varieties are to be found from the littoral zone to considerable depths. There seems, however, to be little agreement in regard to, or scientific classification of, the varieties.

Whelks are used at many of the fishing ports along the coast as bait for the long lines. They are caught by the Manx fishermen from banks of a shelly nature, about 17 to 20 fathoms deep, often near beds of the scallop *Pecten opercularis*. The method employed is to sink wicker baskets (crab or whelk pots) of the kind used for capturing the edible crab, baiting them usually with the latter animal. The crabs are used fresh, and are strung

on a piece of cane which is inserted in the basket. An average catch at Port Erin is about 20 to 25 whelks per two days.

The whelk is also used as food, and large quantities are usually exposed for sale in London. It does not appear to be eaten much in the North of England, but a few specimens are occasionally seen for sale in Liverpool. In the Isle of Man, and Scotland, the whelks are commonly termed "buckies"; in Heligoland "coxen," and in the days of British rule, the English fishermen who called there were known as "coxen clappers," from their habit of breaking up the shells to obtain the whelk for bait.

Joubin states* that *Buccinum undatum* is very common on the West Coast of France, and that in the Syndicat of Portbail a fisherman can collect as many as 200 at one low tide. These he can sell at 1d. to 3d. per dozen. They are consumed in the country, and not exported.

A considerable demand for whelks must, however, still exist in this country, and one finds quotations regularly in the *Fish Trades Gazette*, though, unfortunately, the quantities sold or brought in are not indicated. The prices at Billingsgate appear to vary from about 4s. to 10s. a bushel. Government reports give little information, whelks being tabulated with other edible animals as "unclassified shell-fish," in the statistics published by the Board of Agriculture and Fisheries; but Mr. C. E. Fryer, I.S.O., of the Fisheries Department of the Board, has very kindly supplied Prof. Herdman with the following particulars collected for last year:—

* Bull. de L'Institut Oceanograph. Monaco. No. 213, July, 1911.

QUANTITY AND VALUE OF WHELKS RETURNED AS LANDED
AT STATIONS IN ENGLAND AND WALES IN 1911.

Station.	Quantity	Value.
<i>East Coast—</i>	cwts.	£
Grimsby	1,292 ...	355
Lynn	5,293 ...	1,039
Wells	12,758 ...	2,218
Sheringham	8,074 ...	1,131
Harwich	4,482 ...	869
Brightlingsea	275 ...	51
East Swale	360 ...	144
Whitstable	10,022 ...	2,256
Ramsgate	586 ...	175
Total.....	43,142	8,238
<i>South Coast—</i>		
Eastbourne	497 ...	149
Selsey	686 ...	171
Portsmouth	774 ...	115
Southampton	337 ...	165
Total.....	2,294 ...	600
Other Stations	1,014 ...	272
TOTAL	46,450 ...	9,110

The returns and remarks in trade journals with reference to Billingsgate are reflected in the statements made in the Annual Reports of the Inspectors of Fisheries for England and Wales. Thus one finds that practically the only ports where whelk-fishing is carried on are situated between Grimsby and Southampton. This probably means that the fishery is governed by the presence of a large market for the mollusc in the south-eastern area of England.

The following official statement shows the small extent of the fishery in the Lancashire and Western Sea Fisheries District:—

Landed at Liverpool—

	Wt. in cwts.	Value in £'s.
1906	nil.	nil.
1907	3 cwts.	nil.
1908	4 cwts.	1
1909	1 cwt.	nil.
1910	1 cwt.	nil.
1911	nil.	nil.

As a matter of fact, however, the real value of the fishery must be higher than is represented by these figures. It is known that four to five hundred whelks are landed weekly by small sailing boats, and these sell at 1s. to 1s. 3d. per hundred. In addition to these, others are apparently landed by longshore fishermen and find their way with illegal-sized flat fish into some of the smaller fish-shops.

In addition to whelk-catching by means of wicker pots, dredges are occasionally used; "trotting" is another method adopted in the south-eastern districts of England. A number of shore crabs are strung together with a needle and string, so as to make a bunch. These are sunk to the bottom and left for a time; they are afterwards drawn up and the whelks removed from them.

In England, some years back, the trade in whelks must have been of considerable importance, for one finds that the Lynn fishery alone supplied about 1,250 tons a year, for which about £10,000 was paid, and Grimsby exceeded this with a value of £22,000. These figures probably include *Fusus antiquus* (the "hard whelk"), which seems to have been more prized in some markets.

The name *Buccinum* comes from "buccina," a trumpet, but it is difficult to get evidence that *Buccinum undatum* was ever used as a musical instrument. Species of *Triton* seem to be most used for this purpose, and *Turbinella* (the Chank Shell) is used in Ceylon by the Buddhists. The Chinese use a species of *Fusus* for the same purpose. The shell of *Fusus antiquus* is also used occasionally in the Scottish Isles as a rude lamp, in which to burn the oil of sea-birds.

The two closely related families, the Muricidae and Buccinidae, contain various genera and species, which have figured, perhaps, more than most marine animals, in the histories and traditions of ancient peoples. They have played an important part in religion, mythology and war, in the production of ornaments, and in the preparation of the famous "Tyrian" purple dyes.

The whelk crawls about the sea-bottom by means of its muscular foot, and when kept in large aquarium tanks occasionally creeps above the level of the water. It seems to remain, however, about a foot or so above the surface, and never crawls further up. It was observed at Port Erin, on every occasion on which whelks were turned into a large tank into which a stream of water was running, that they found their way towards the entrance pipe. They then remained either just below or just above the level of the water, in the latter case bathed by the spray, although the water was well aerated in every part of the tank.

The whelk appears to be omnivorous so far as its diet is concerned, and dead (but fresh) or living organisms seem equally acceptable. The food, which is scraped away by its jaw apparatus, is taken into the stomach in a finely divided state, and little information as to its character can be gathered from an examination of the stomach contents.

The fishermen at the Isle of Man have found that the best bait for their whelk-pots is *Cancer pagurus*, the edible crab, used fresh. The whelk inserts the proboscis through the holes broken into the carapace of the crab. Whelks have been observed to attack living lamellibranchs, and on one occasion at Port Erin a large specimen of *Buccinum* was observed to prevent a *Pecten maximus* from closing its valves by inserting the anterior end of the shell between them. It then attacked the adductor muscle with its long proboscis, and so at the same time obtained food and disabled the closing mechanism of the scallop. The same process of disabling the prey has been observed by Colton in the American genera *Fulgur* and *Sycotypus*. Colton experimented with these animals, and found that when an oyster was given to a hungry *Sycotypus*, the latter crawled on the top of the oyster and waited until the valves were opened. It then rotated on the columella and inserted the end of its own shell between the valves. Forty minutes later it left an empty shell. *Fulgur* actually hammers the margin of lamellibranch shells by grasping with its foot and contracting the columellar muscle sharply. The proboscis is then inserted into the orifice so made. The impression one usually derives from the literature of the subject is that the whelk actively bores through lamellibranch shells by means of its odontophore. Colton states, however, that the radular teeth of *Fulgur*, *Nassa*, *Lunatia* and *Purpura* do not appear as if worn down against a hard substance, but broken off irregularly. To this list the whelk can be added, for the old teeth present a most ragged appearance (fig. 15).

On one occasion a whelk was observed attacking a dead *Nephrops* (the Norway lobster). It held the crustacean by means of the anterior part of the foot,

using the latter to envelop the posterior part of the abdomen of its prey. The radula was then brought into action, and a hole was bored through the chitinous exoskeleton until the proboscis could reach the muscles. Here again the use of the foot as a grasping organ may be noticed. In its turn the whelk must fall a prey to many other inhabitants of the sea, and one often wonders what has happened to the former owners of the numerous whelk shells now found occupied by hermit crabs (see Text-fig. on p. 350).

The cod feeds to a certain extent upon the whelk, though this is by no means its chief food. Remains of the whelk have also been found in the stomach of the dog-fish. Curiously enough, in most cases these remains include only the fleshy part of the animal and the operculum. This implies that, contrary to expectation, the fish either bites off the protruding part of the whelk or otherwise achieves the apparently impossible in removing the animal from its shell.

Quite recently, Dr. C. G. Joh. Petersen has published a very interesting paper on the relations of the whelk to the fisheries of Denmark. In 1909 a committee was formed in that country to consider the harmful animals of the sea-fisheries; and five animals were black-listed—the sea scorpion, the stickleback, crabs, starfish, and whelks. Petersen suggested that before money was spent on efforts to exterminate these creatures, experiments should be made to determine the possibility of such a proceeding. The whelk was selected for the experiments, and the Board of Agriculture allotted funds for the work. The harm done by the whelks was known and had been investigated some time earlier (1895). It had been found that the whelk attacked the plaice entangled in fishing-nets. Although unable to seize actively-moving fish,

they very soon found and attached themselves to the fish that had been caught. The whelk proceeds by boring a hole through the skin, inserting its snout, and then devouring all the muscular tissue, leaving nothing but skin and bones. The mollusc will not touch rotten fish, but experiments have shown that it will devour anything so long as it is fresh. Often enough, 10 to 20 whelks would be found attached to a plaice, and the fishermen estimated that one-third of the year's catch was lost in the region investigated (Thisted Bredning, in Denmark).

The experiments carried out by Petersen were of a two-fold nature—(1) to determine the number of whelks in a certain area, and (2) to find out whether these could be economically exterminated by capture. The first part of the work was carried out by using an instrument called the “bottom-sampler,” and also by the employment of a diver. The latter caught from 106 square metres 100 whelks, 36 square metres 128 whelks, 106 square metres 70 whelks, 106 square metres 97 whelks. In the last two cases the man reckoned that he had only taken one-third of the whelks present. From the results it was calculated that 130 million whelks were present in the region (an area of 65 million square metres).

One motor boat, with 240 traps, was able to catch 3,845½ bushels (45 tons of whelks!) in the same district, between April 5th and November 8th.

On the whole, it was concluded that the extermination by catching would not be an economic method, especially since there did not seem to be any great use for the whelks caught in the district. Petersen also states that six or seven whelks' opercula may be found in one cod's stomach, and comments on the rarity of any remains of the shells.

PARASITES.

Two extremely interesting parasites have been found in the whelks from Port Erin. One of these is a Coccidian (*Merocystis kathae*, Dakin), and the other is an endoparasitic Turbellarian first found 14 years ago by Jameson, and re-discovered this year in whelks from the same district. The Turbellarian (*Graffilla buccinicola*) belongs to a genus of parasitic rhabdocoeles which occurs frequently in mollusca, but at the time of Jameson's discovery *Graffilla* had not been found in British waters. No further details of its anatomy will be given here, because it seems advisable that the species should undergo a thorough re-examination. One point, however, must be referred to. Jameson states that the parasite occurs in the kidney and "kidney duct" of *Buccinum undatum* and *Fusus antiquus*, and that almost all whelks examined were infected. My specimens were examined fresh, and considerable numbers were investigated. In all cases the parasites were found in the *stomach* and *rectum*, and there were as many as 14 seen in the stomach of one individual.

It is somewhat difficult to conjecture what the "kidney duct" referred to in Jameson's description can be, for the renal organ opens directly at one end into the mantle cavity. The minute reno-pericardial canal can hardly be called a kidney duct!

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EXPLANATION OF PLATES

REFERENCE LETTERS

- A. buc.* = Buccal artery.
A. c. = Anterior aorta.
A. cut.' = Cutaneous artery.
A. col. = Columella artery.
A. g. = Gastric artery.
A. go. = Gonad vessels.
A. pall. = Pallial artery.
A. ped. = Pedal artery.
A. pen. = Penis artery.
A. vis. = Visceral artery.
Af. ct. = Afferent branchial vessel.
An. = Anus.
Ao. = Aorta.

Br. v. = Branchial vessels.
bucc. = Buccal ganglia.
c. = Cerebral ganglion.
C. c. = Occlusor muscle.
C. cav. = Blood spaces in oesophagus.
C. p. = Cerebro pedal connective.
c. d. m. = Centro dorsal muscle.
c. gr. = Granular cells of renal lamella.
Caec. = Oesophageal caecum.
cae. w. = Connective tissue of caec. wall.
cart. = Cartilage.
cer. com. = Cerebral commissure.
Col. mus. = Columella muscle.
Con. t. = Connect. tiss. gland of Leiblein.
Con. = Connective tissue.
Cor. = Cornea.
Ct. = Ctenidium.
ct. ax. = Ctenidial axis.
ct. con. = Connective tissue of gill leaflet.
ct. e.' = Epithelium of gill leaflet.
ct. ep. = Ctenidial epithelium.
ct. gl. = Connect. tissue of ctenidial axis.
ct. mus. = Ctenidial muscles.
ct. n. = Ctenidial nerve.

D. m. s. = Dorsal trans. muscle sheet.
D. pr. m. = Dorsal protractor muscles.
Dg." = Lobe of stomach.
Dg.c." *Dg.c.'* = Cells of digestive gland.

Dg. con. = Connective tissue of gland.
Dg.d. = Opening of post. digestive gland duct.
Dg.d.' = Opening of ant. dig. gland duct.
Dg. gl. = Digestive gland.
Dg. gr. = Granules of gland cells.
Dg. nuc. = Nucleus of gl. cell.

Eff. ct. = Efferent branchial vessel.

Foot = Foot.
Foll. ep. = Follicular epithelium.

Ge. ep. = Germinal epithelium.
Gl. c. = Gland cells.
Go. = Gonad.

l.r.r. = Dorsal retractor muscles.
L.t.b. = Lateral odontophoral bands.
Lam. pr. = Lamellae of secondary system.
Lam. v. = Vein of renal lamella.
Lens = Lens.
Ling. con. = Connective tissue of odontophore.
Ln. g. = Gland of Leiblein.

M. = Mouth.
m.v.r. = Median ventral muscles.
mem. = Membranous wall of larva.
Mu. gl. = Mucous gland.
Mus. circ. = Circular muscles.
Mus. col. = Transverse sections of mus. fibres.

N. ax. = Nerve of ctenidial axis.
n.ot. = Otocyst nerve.
neph. gl. = Nephridial gland.
Nuc. = Nucleus.
Nuc. Int. C. = Nuclei of interstitial cells.

O. cav. = Lumen of oesophagus.
oe. con. = Connective tissue with longitud. muscles.
oe. con.' = Connective tissue.
oes. = Oesophagus.
Op. = Operculum.
Op. n. = Optic nerve.

Os. n. = Osphradial nerve.
Osp. cil. = Ciliated cell region of osphrad. leaflets.
Osp. gl. = Gland cell region of osphrad. leaflets.
Osp. so. = Sensory cell region of osphrad. leaflets.
Osph. = Osphradium.
Ot. = Otocyst.
ov. = Ovary (oviduct in figs. 38 and 37).
ova. = Eggs.
ovd. = Oviduct.
ovd.''' = Vaginal part of oviduct.

P. = Penis nerve.
Pall. = Mantle.
Pall. ep. = Mantle epithelium.
Pall. gl. = Mantle conn. tissue.
pall. n. & n.'' = Pallial nerves.
Ped. g. = Pedal ganglia.
Ped. gl. = Pedal gland.
ped. gr. = Pedal groove.
ped. mus. = Pedal muscles.
ped. n. = Pedal nerves.
Pen. = Penis.
Per. p. = Pericardial cavity.
Ph. = Pharynx.
Pig. = Pigment.
pl. l. = Left pleural ganglion.
pl. p. = Pleuro-pedal connective.
pl. r. = Right pleural ganglion.
pr. = Processes of retinal cells.
prob. = Proboscis.
prob. m. = Proboscis muscles.
Ps. cor. = Pseudo cornea.
Pul. = Larval heart.

r.' & r.'' = Retractor muscles (dorsal).
R. Sin. = Reno-mucous vessel.
Rect. = Rectum.
Ren. = Renal organ.
ren. cil. = Ciliated cells of renal epithelium.

ren. eff. = Vessels of renal organ.
ren. ep. = Renal epithelium.
ren. lam. = Renal lamella.
ren. r. = Renal ridges.
Ret. c. = Retinal cells.
rhyn. = Rhynchodoeum.
Rst. = Rhynchostome.

S. = Stomach.
S. gl. c. = Salivary gland cells.
Sal. d. = Salivary duct.
Sal. gl. = Salivary gland.
Siph. = Pallial siphon.
Siph. n. = Siphon nerves.
Sptd. = Spermatid.
Spte. = Spermatocyte.
Spz. = Spermatozoa.
St. = Stomach.
St. s. = Stiftchen.
sub. int. = Subintestinal ganglion.
sup. int. = Supraintestinal ganglion.
sup. m. = Supporting structure of tentidial leaflets.

Tent. = Tentacle.
tent. = Tent. nerve (fig. 42).
tri. lat. = Triangle lateral.

V. def. = Vas deferens.
V. def.' = Coiled part of vas deferens
V. def.'' = Vas deferens in penis.
V. def. c. = Vas deferens canal.
V. e. m. = Ventral muscle sheet.
V. pr. m. = Ventral protractor muscles.
V. r. = Retractor muscles (dorsal).
v. r. m. = Ventral retractor muscles.
vas. d. = Vas deferens.
vel. = Velum.
vis. com. = Visceral commissure.

X. con. = Connect. tissue of mantle.
Zyg. = Zygoneuric connection.

PLATE I.

- Fig. 1. Shell of *Buccinum undatum*. $\times \frac{4}{5}$
 Fig. 2. Section of Buccinum shell, showing septa at apex. $\times \frac{5}{6}$
 Fig. 3. View of part of columella of 5th whorl, showing attachment of columellar muscle. $\times \frac{3}{2}$
 Fig. 4. Surface view of periostracum.
 Fig. 5. Superior surface of operculum. $\times 1$.
 Fig. 6. Longitudinal section of shell. $\times 40$.
 Fig. 7. General view of animal after removal of shell. $\times 1$.

PLATE II.

- Fig. 8. Roof of pallial cavity with organs of pallial complex. \times slightly.
 Fig. 9. Ventral surface of foot (expanded). $\times \frac{1}{2}$.
 Fig. 10. Transverse section of pedal groove and gland. $\times 17$.
 Fig. 11. Dissection showing cavity into which proboscis sheath is retracted and also rhynchocoel in which proboscis lies. $\times 1$.
 Fig. 12. Dissection of alimentary canal. Slightly reduced.
 Fig. 13. Stomach as seen from digestive gland surface. Slightly reduced.
 Fig. 14. Radula with teeth. $\times 48$.
 Fig. 15. Old teeth. $\times 64$.

PLATE III.

- Fig. 16. General view of odontophore, radula and muscles from above. Slightly magnified.
 Fig. 17. Ventral end of radula with attached ventral retractors. Slightly magnified.

- Fig. 18. Odontophoral cartilage (odontophoral tongue) with ventral muscles indicated through it. Slightly magnified.
- Fig. 19. Odontophore from above before muscles are laid bare by cutting dorsal transverse sheath. Slightly magnified.
- Fig. 20. Odontophoral tongue.
- Fig. 21. Anterior end of odontophoral cartilage with ventral protractor muscles.
- Fig. 22. Transverse section of cartilage and radula muscles. $\times 480$.
- Fig. 23. Transverse section near tip of odontophoral tongue.
- Fig. 24. Transverse section of pharynx wall. $\times 200$.
- Fig. 25. Transverse section of oesophagus. $\times 30$.

PLATE IV.

- Fig. 26. Section through salivary gland and duct. $\times 450$.
- Fig. 27. Epithelium of oesophagus. $\times 800$.
- Fig. 28. Transverse section of oesophageal caecum. $\times 50$.
- Fig. 29. Transverse section of digestive gland. $\times 200$.
- Fig. 30. Section through wall of Gland of Leiblein. $\times 450$.
- Fig. 31. Transverse section through two gill leaflets.
- Fig. 32. Transverse section through gill leaflet more distal to fig. 31.
- Fig. 33. Transverse section through gill leaflet more distal to fig. 32.

(The three sections are consecutive and all $\times 100$.)

- Fig. 34. Cells from inner surface of wall of gill. $\times 800$.

PLATE V.

- Fig. 35. General view of superficial blood vessels.
Slightly enlarged.
- Fig. 36. General view of arterial system. Slightly
enlarged.
- Fig. 37. Venous System and especially circulation in
Renal Organ. $\times 1$.
- Fig. 38. Veins on external surface of Oviduct, etc.
 $\times 1$.

PLATE VI.

- Fig. 39. Transverse section of Ctenidial axis. $\times 40$.
- Fig. 40. Transverse section of Mucous gland. $\times 50$.
- Fig. 41. Nervous system. $\times 1$.
- Fig. 42. Anterior Nerve centres, view from inside of
nerve collar. $\times 6$.
- Fig. 43. Pedal Ganglia in male. $\times 6$.
- Fig. 44. Two leaflets of Osphradium. $\times 10$.
- Fig. 45. Transverse section of osphradial leaflets.
 $\times 70$.
- Fig. 46. Cells from osphradium (maceration prepara-
tion). $\times 400$.

PLATE VII.

- Fig. 47. Transverse section through eye. $\times 140$.
- Fig. 48. Cells from retina (maceration preparation).
 $\times 400$.
- Fig. 49. Outer wall of renal organ with renal filaments
seen from the lumen. $\times 1$.
- Fig. 50. Nephridial Gland seen from inner surface
(facing lumen of renal organ). $\times 1$.
- Fig. 51. Outer wall of renal organ after removal of
renal filaments, showing secondary lamellae.
 $\times 1$.

- Fig. 51a. Diagram showing how blood passes to renal filaments by vessels crossing the lumen of the renal organ.
- Fig. 52. T.S. Renal filaments. $\times 200$.
- Fig. 53. T.S. Secondary lamella. $\times 200$.
- Fig. 54. Male gonad and ducts with penis. $\times 1$.
- Fig. 55. Female gonoducts. $\times 1$.

PLATE VIII.

- Fig. 56. Section of tubule of testis showing formation of spermatozoa. $\times 1$.
- Fig. 57a. Spermatid.
- Fig. 57b. "Hair-like" spermatozoon
- Fig. 57c. "Worm-like" spermatozoon } after Retzius.
- Fig. 58. Transverse section of ovary. Very slightly magnified.
- Fig. 59. Transverse section of vaginal part of oviduct. Slightly magnified.
- Fig. 60. Transverse section of ovary. $\times 150$.
- Fig. 61. Under surface of egg capsule showing pore of escape. $\times 1$.
- Fig. 62. Early stage in development of larva after cannibalism (after Koren and Daniellsen).
- Fig. 63. Very early larval stage, otocysts present. (after K. and D).
- Fig. 64. Late veliger larva (original). $\times 50$.
- Fig. 65. Egg capsules. Slightly reduced.
- Fig. 66. Shells of young Buccinum at time of departure from egg capsules. $\times 10$.

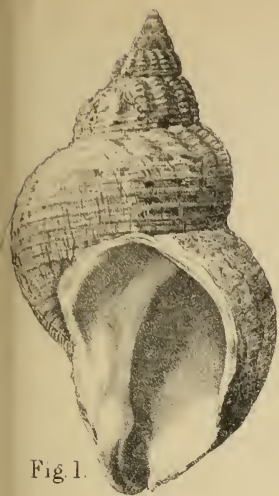


Fig. 1.

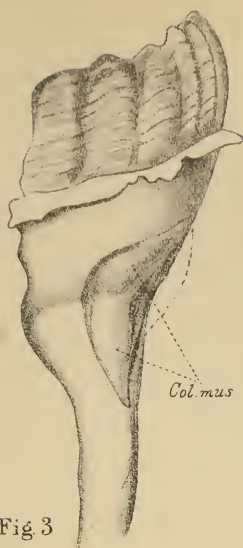


Fig. 3.



Fig. 2.



Fig. 6.

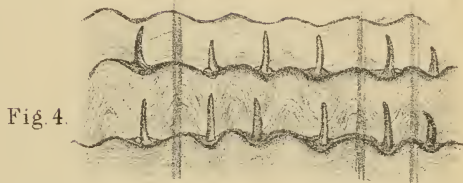


Fig. 4.



Fig. 5.

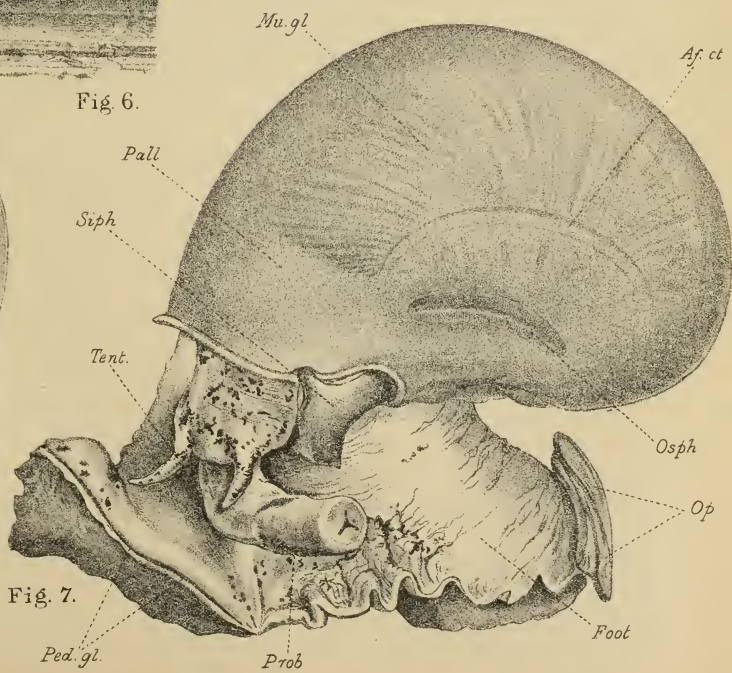


Fig. 7.

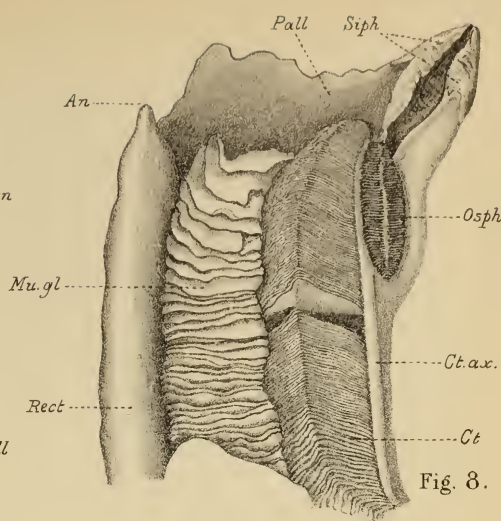
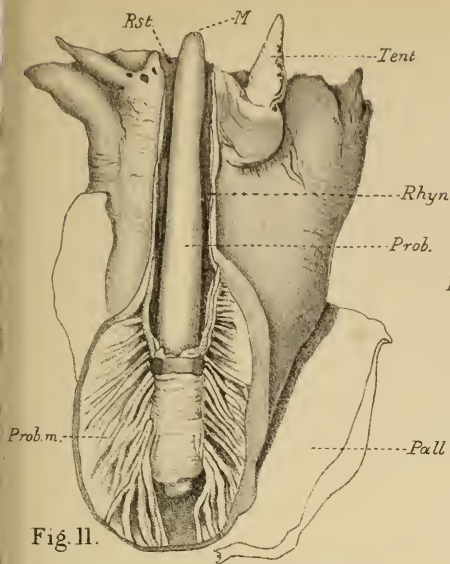


Fig. 8.

Fig. 11.



Fig. 9.

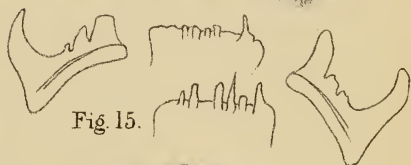


Fig. 15.

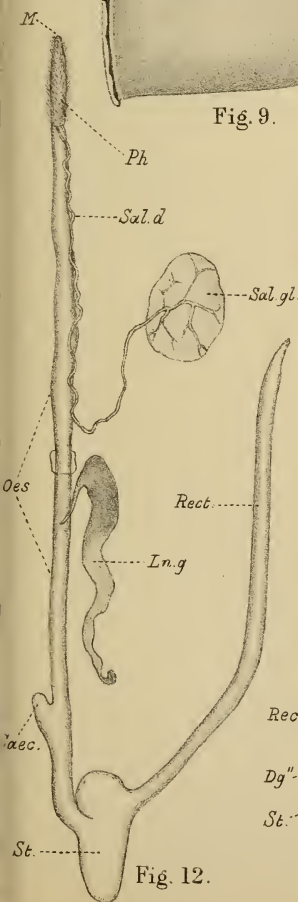


Fig. 12.



Fig. 10.

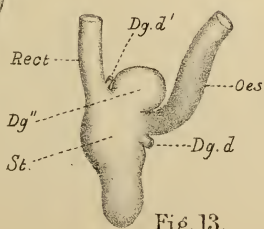


Fig. 13.

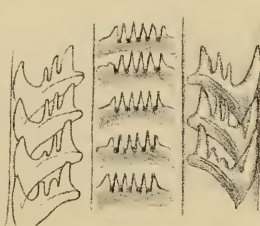
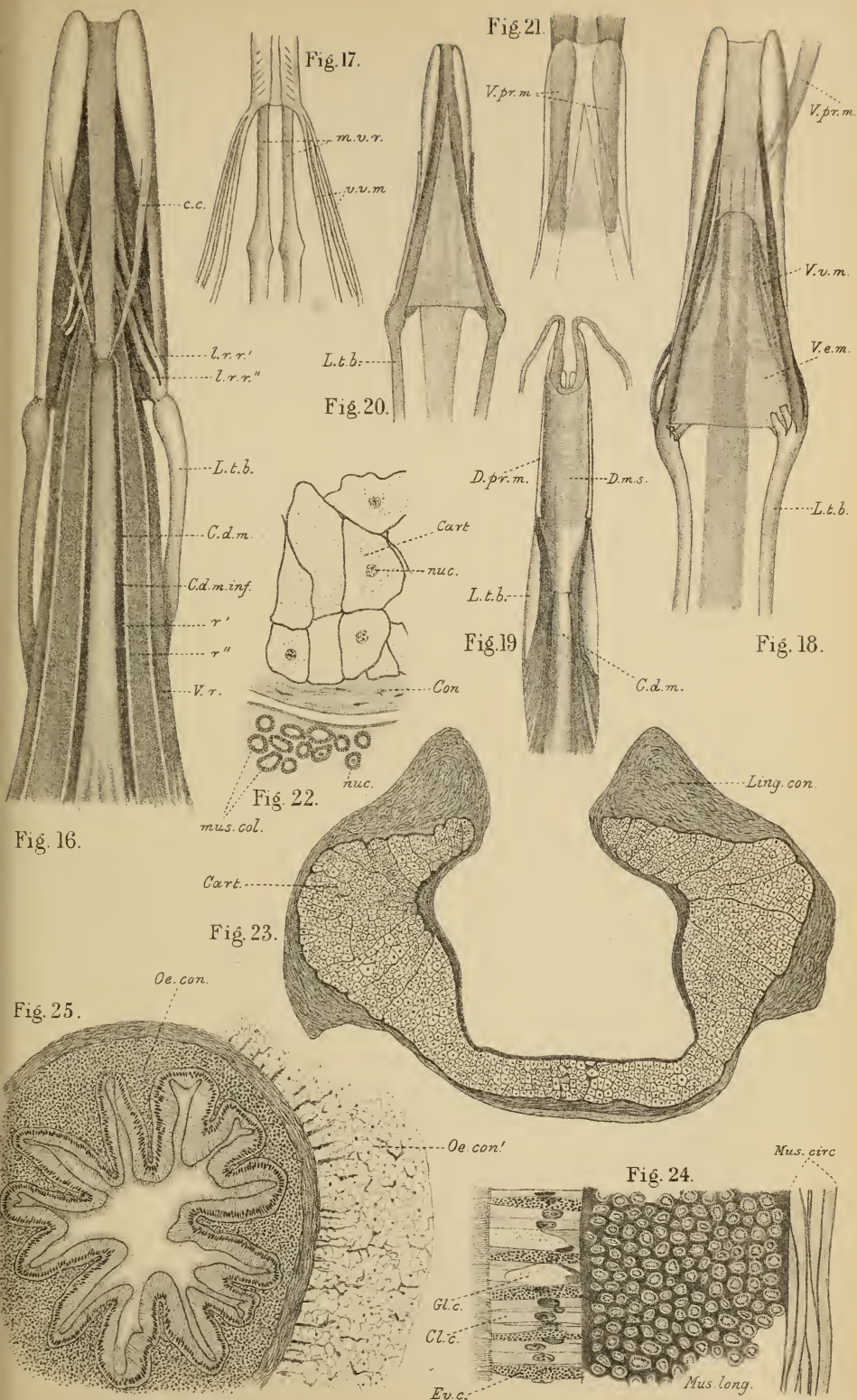


Fig. 14.



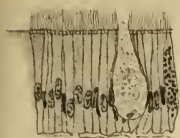


Fig. 27.

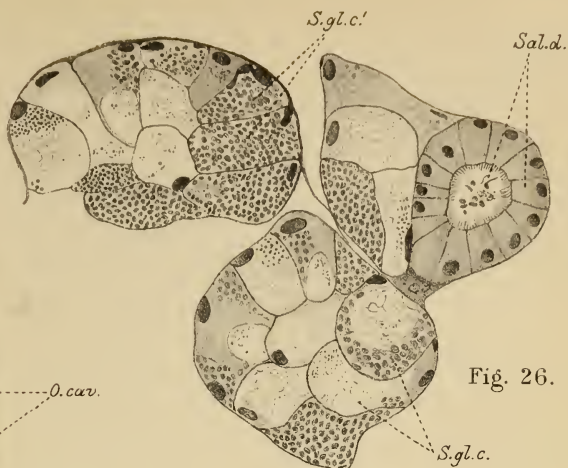


Fig. 26.

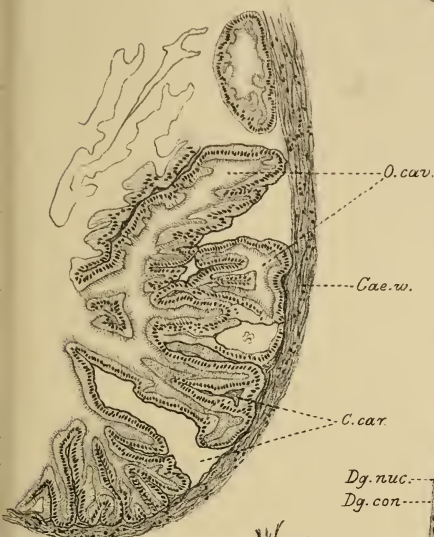


Fig. 28.

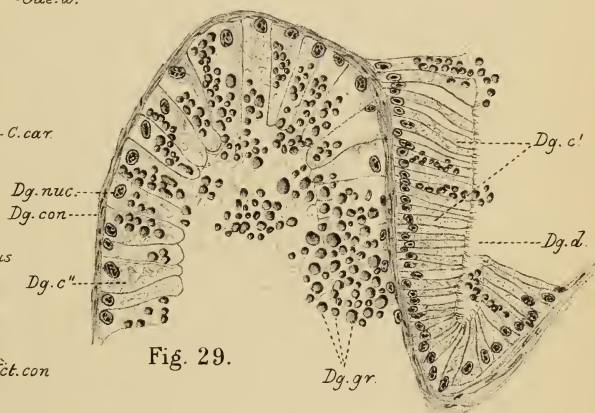


Fig. 29.



Fig. 34.



Fig. 33.

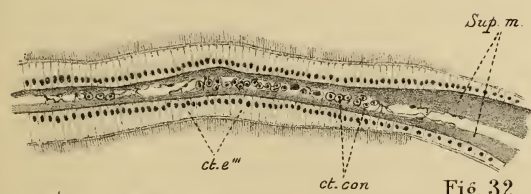


Fig. 32.



Fig. 30.

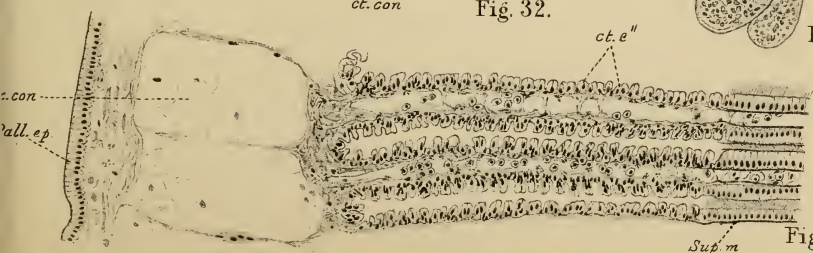


Fig. 31.



Fig. 38



A. ped.

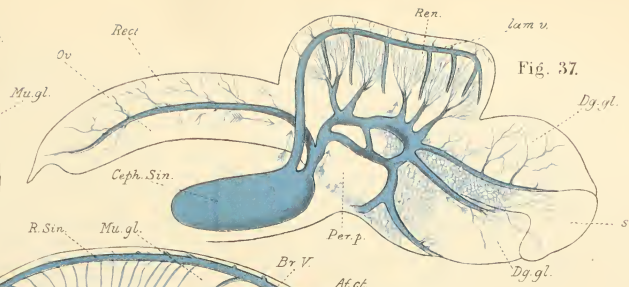


Fig. 38.

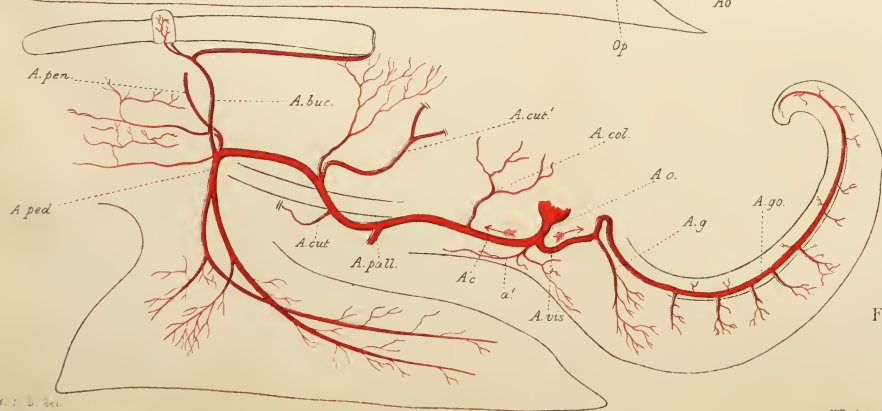
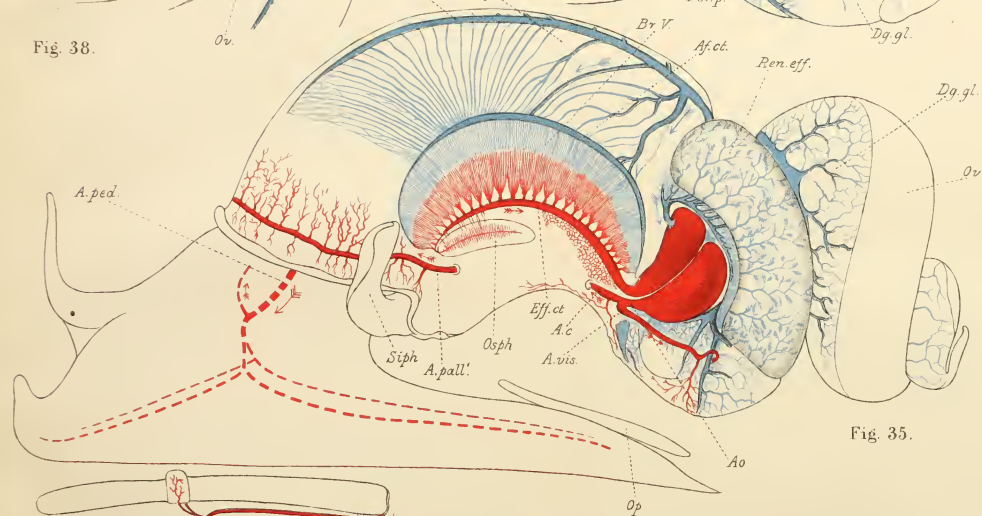




Fig. 40.

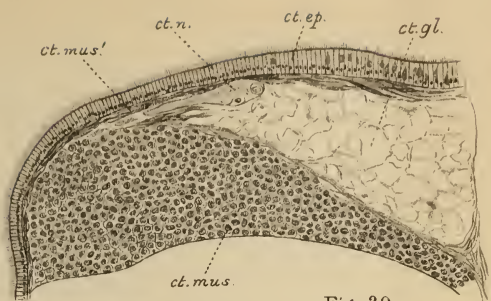


Fig. 39.

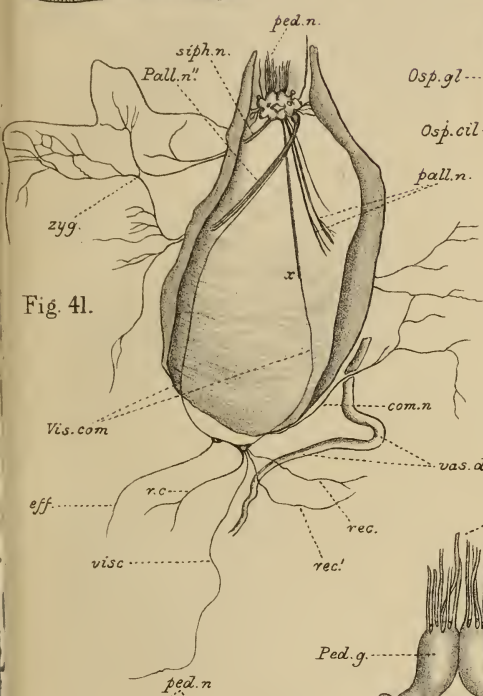


Fig. 41.

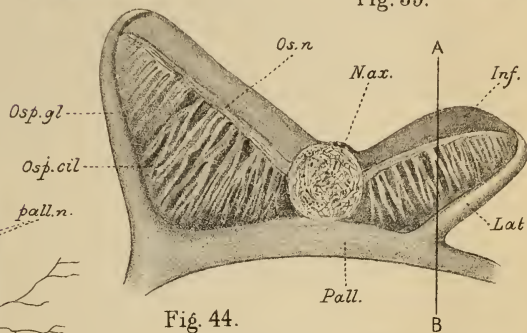


Fig. 44.

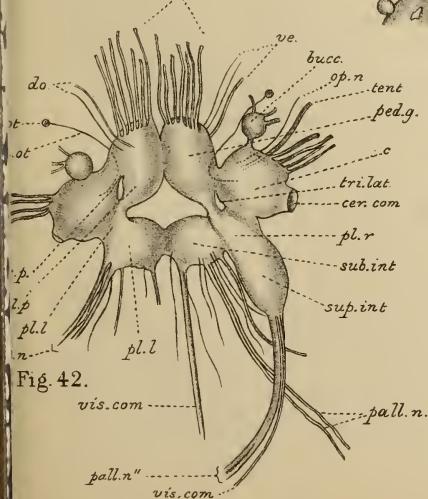


Fig. 42.

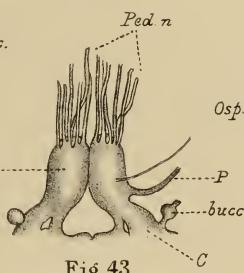


Fig. 43.

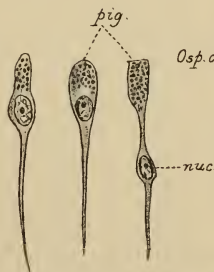


Fig. 46.

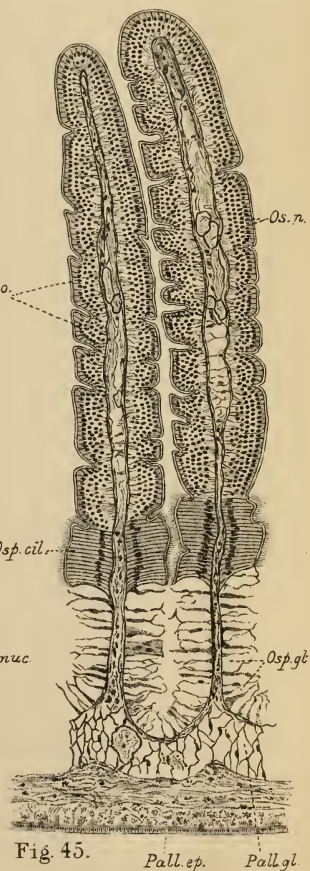


Fig. 45.

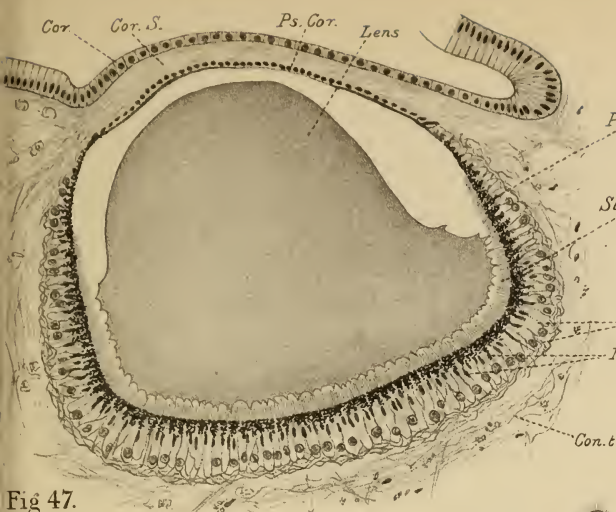


Fig. 47.

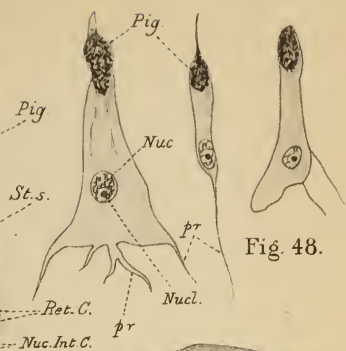


Fig. 48.



Fig. 50.

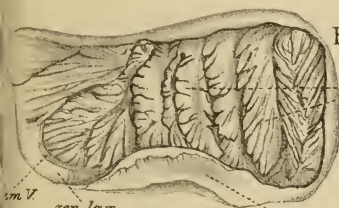


Fig. 49.



Fig. 51A

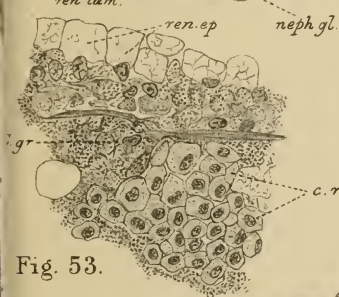


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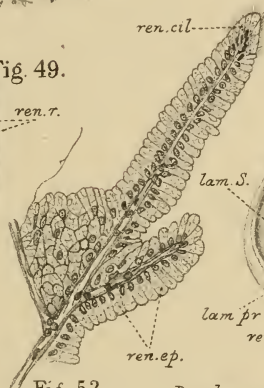


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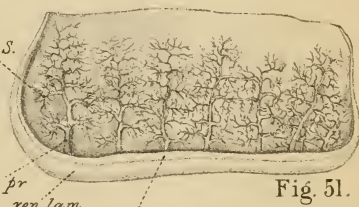


Fig. 51.



Fig. 53.

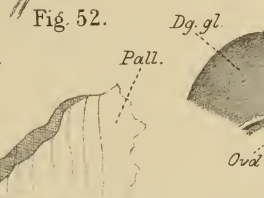


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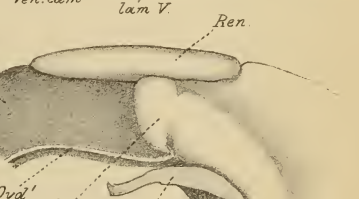


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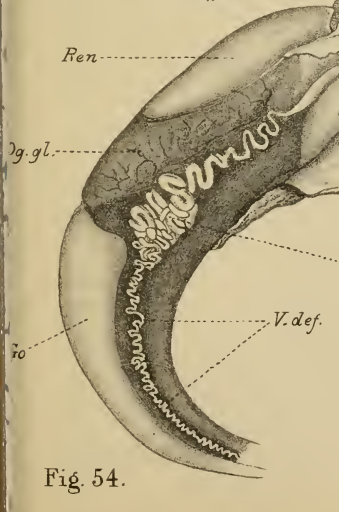


Fig. 54.

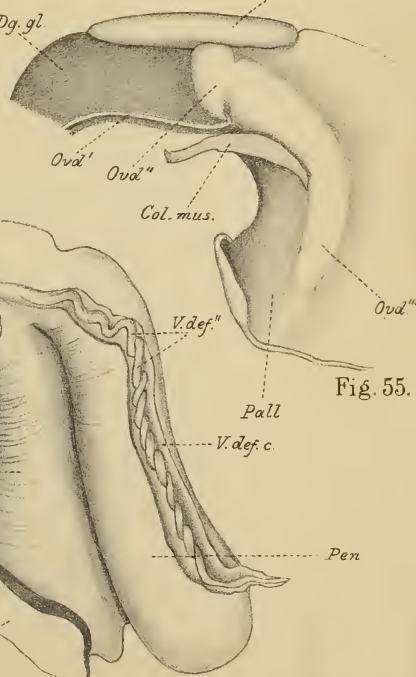


Fig. 55.



Fig. 56.

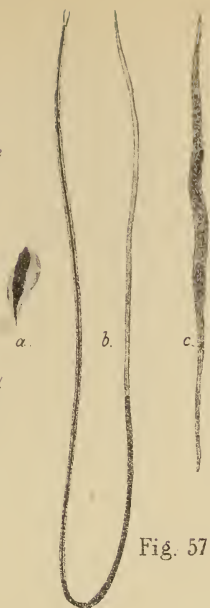


Fig. 57.



Fig. 60.

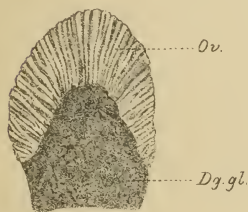


Fig. 58.



Fig. 63.



Fig. 61.

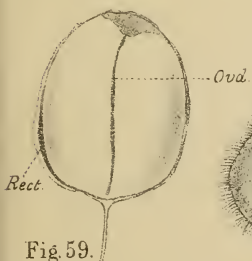


Fig. 59.

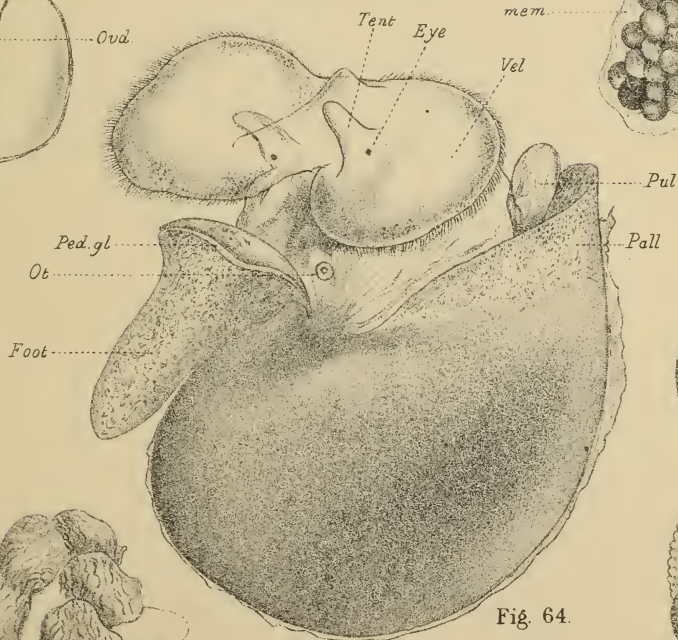


Fig. 64.



Fig. 62.



Fig. 66.



Fig. 65.



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